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CONTENTS

PAGE

Arvy, Mlle Lucie. Données sur la leucopoièse chez *Musca domestica* L. 39

Bailey, L. The filtration of particles by the proventriculi of various Aculeate Hymenoptera 119

Basden, E. B., F.R.E.S. Diapause in *Drosophila* (Diptera : Drosophilidae) . . 114

Brown, E. S., B.A., F.R.E.S. Report on Corixidae (Hemiptera) taken in light-traps at Rothamsted Experimental Station 17

Buxton, Prof. P. A., C.M.G., F.R.S., F.R.E.S. British Diptera associated with fungi. 2.—Diptera bred from Myxomycetes 163

Dobson, Ronald M., F.R.E.S. A note on the anatomy and morphology of the external genitalia of *Carpophilus obsoletus* Er. (Coleoptera : Nitidulidae) 45

Dunn, J. A., M.Sc. *Micromus variegatus* as a predator of the pea aphid 76

Eastop, V. F., F.R.E.S. The males of *Rhopalosiphum maidis* (Fitch) and a discussion on the use of males in aphid taxonomy 84

Hickin, N. E., Ph.D., F.R.E.S. Larvae of the British Trichoptera—41 55

Hickin, N. E., Ph.D., F.R.E.S. Larvae of the British Trichoptera—42 59

Hickin, N. E., Ph.D., F.R.E.S. Larvae of the British Trichoptera—43 89

Hickin, N. E., Ph.D., F.R.E.S. Larvae of the British Trichoptera—44 93

Hickin, N. E., Ph.D., F.R.E.S. Larvae of the British Trichoptera—45 96

Hickin, N. E., Ph.D., F.R.E.S. Larvae of the British Trichoptera—46 145

Hickin, N. E., Ph.D., F.R.E.S. Larvae of the British Trichoptera—47 153

Hickin, N. E., Ph.D., F.R.E.S. Larvae of the British Trichoptera—48 172

Hickin, N. E., Ph.D., F.R.E.S. Larvae of the British Trichoptera—49 174

Hinton, H. E., Ph.D., F.R.E.S. On the structure and function of the respiratory horns of the pupae of the genus *Pseudolimnophila* (Diptera : Tipulidae) 135

Jackson, C. H. N., D.Sc., Ph.D., F.R.E.S. Bionomics of some African Asilidae . 81

Leftwich, A. W., B.Sc., F.Z.S. Vision and blindness in Mosquito larvae as indicated by the submerging reflex 156

Leston, D., F.R.E.S. Wing venation and male genitalia of *Tessaratoma* Berthold, with remarks on Tessaratominae Stål (Hemiptera : Pentatomidae) 9

Lewis, D. J., F.R.E.S., Henry, A. J., and Grindley, D. N. Daily changes in the numbers of Chironomid midges at Khartoum 124

Mackereth, Mrs. Jean C., Taxonomy of the larvae of the British species of the genus *Rhyacophila* (Trichoptera) 147

Nayar, K. K., M.A., Ph.D. Metamorphosis in the integument of Caterpillars with omission of the pupal stage 129

Popham, Edward J., D.Sc., Ph.D., F.R.E.S. A new and simple method of demonstrating the physical gill of aquatic insects 51

Ribbands, C. R., M.A., F.R.E.S. Communication between honeybees. I : The response of crop-attached bees to the scent of their crop 141

Slifer, Eleanor H., F.R.E.S. The reaction of a grasshopper to an odorous material held near one of its feet (Orthoptera : Acrididae) 177

Smith, F. G., B.Sc.(For.). Notes on the biology and waxes of four species of African *Trigona* bees (Hymenoptera : Apidae) 62

Stroyan, H. L. G., M.A., F.R.E.S. Notes on the early stages of *Rhopalus parumpunctatus* Schill. (Hemiptera : Coreidae) 32

Taylor, J. Sneyd, M.A., D.I.C., F.R.E.S. Notes on further parthenogenetic generations of a species of *Mesocelis* (Lasiocampidae) from the Eastern Karoo . . 71

Thomas, Joan G., Ph.D. The post-embryonic development of the flight muscles of *Lamarckiana* sp. (Orthoptera) and a brief comparison of these with those of *Saussurea stuhlmannia* (Karsch) and *Tanita dispar* (Miller) 23

Venkatraman, T. V., and Subba Rao, B. R. The mechanism of oviposition in *Stenobracon deesae* (Cam.) (Hymenoptera : Braconidae) 1

Wallace, H. R., Ph.D., F.R.E.S. Notes on the biology of *Arhopalus ferus* Mulsant (Coleoptera : Cerambycidae) 99

Book Notices.

Albrecht. The anatomy of the migratory locust 42

Bátorliget élővilága 86

Burr. The insect legion 87

Butler. The world of the honeybee 87

Ferris. Atlas of the scale insects of North America. Vol. VI 88

Massee. The pests of fruit and hops 87

Richards. The social insects 42

Walker. The Odonata of Canada and Alaska. Vol. 1 88

THE MECHANISM OF OVIPOSITION IN *STENOBRACON DEESAE* (CAM.)[1] (HYMENOPTERA : BRACONIDAE).

By T. V. VENKATRAMAN[2] and B. R. SUBBA RAO[3].

(*Indian Agricultural Research Institute, New Delhi, Indian Union.*)

Stenobracon deesae (Cam.) is an important ectophagous larval parasite of the lepidopterous borers of sugarcane and maize in India. Cherian and Israel (1938) have worked out the biology of the parasite. A technique for the mass propagation of the parasite on a laboratory host has been recently developed in the Parasite Laboratory of the Indian Agricultural Research Institute (Narayanan and Venkatraman, 1952). The present paper deals with the structure of the ovipositor and the accessory organs and the process of oviposition in this braconid.

TECHNIQUE.

Specimens were killed in benzene vapour and the abdomen of the female was kept in 10 per cent. cold KOH solution for ten to twelve hours. The genitalia, after clearing, were mounted in balsam without staining. For a study of the musculature freshly killed specimens were used, and dissections were made in physiological salt solution under a binocular microscope, after cutting open the abdomen from the dorsal side. The material for section cutting was fixed in Kahle's fluid and sections were cut 6μ thick.

MECHANISM OF OVIPOSITION.

Structure of the Ovipositor and Associated Parts.

The terminology used by Snodgrass (1933) has been followed throughout the paper. The abdomen of the female *Stenobracon* contains nine functional segments. The post-genital segment is represented by the proctiger (fig. 1, *Ptgr*). The seventh, eighth and ninth segments are free and are articulated with the help of broad inter-segmental membranes.

The ovipositor is longer than the body (Pl. I, fig. 3) and extends out from the abdomen between the proctiger and the seventh sternite (fig. 1, *Ovp.*). The seventh sternite projects beneath the base of the ovipositor to form a large plate called the subgenital plate (fig. 1, *VIIS*).

The ovipositor is composed of three pairs of valvulae. In life the third pair of valvulae (fig. 1, *3vl.*), which is the only pair visible, ensheath the ovipositor between their hollowed surfaces. The dorsal pair of valvulae, which is the second pair, is united to form a median structure. The distal end of the second pair is slightly thickened and bent, while the tip of the first pair is serrate on its lower edge (fig. 1, 1*Vl.* and 2*Vl.*). The first and second pairs are joined in such a way that a canal is formed between them (fig. 2, *Pcl.*). Fig. 2 shows the cross section of the ovipositor at the centre. The second valvulae are provided with a pair of rails which fit into the grooves of the first valvulae and form a sort of dove-tail joint. The guide rails run throughout the length of the valvulae except at the distal end. The canal running through the ovipositor serves as a passage for the egg as well as the poison which is pumped down from the reservoir during stinging. The proximal ends of the second valvulae extend into the vestibular cavity and end in a bulb (fig. 4, *blb.*). The bases of the third valvulae are flattened to form the second valvifers and the lateral bases of these articulate with two notches on either side of the bulb (fig. 5, 2*nd vlf*). On the dorsal side of the bulb there is a single short central arm which makes a U-turn back on itself (fig. 4, *arm*). It is a very important structure and serves as the pivot of attachment for some of the large muscle strands which operate the movement of the ovipositor. From the inside of each lateral swelling of the bulb a fine ramus curves upward and attaches itself along the dorsal margin of the corresponding second valvifer. The rami from the first pair of valvulae also curve upwards and make the same attachment with the margin of the first valvifers (fig. 4, *R*1*vl.*, *R*2*vl.*). The first valvifer is a small plate along the posterior aspect of the second valvifer (fig. 5, 1*st vlf.*).

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Act of Stabbing and Paralysation of the Host.

Copulation takes place a few hours after emergence, and the female is ready for oviposition soon after. As soon as the gravid female comes near the sugarcane stem containing the borer, it displays great enthusiasm by constant vibrations of the antennae and repeatedly drawing out the ovipositor between its hind legs. The initial attraction of the parasite to the host appears to be provided mainly by the odour of fresh grass of the host caterpillar. When the parasite comes near the borer hole it keeps the antennae bent downwards, bringing the middle portion in contact with the stem. When the larval burrow is located the parasite moves excitedly round the borer hole and finally takes

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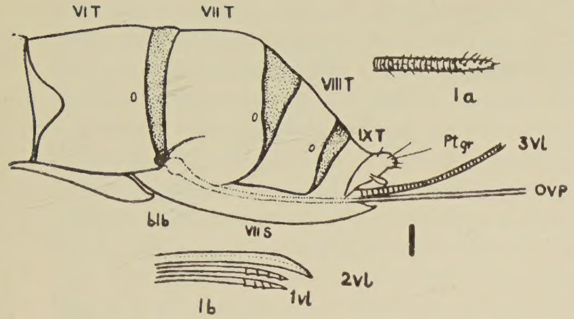
Figs. 1–8.—(1) External side view of female *Stenobracon* abdomen. (*a*) Tip of third valvulae. (*b*) Tip of first and second valvulae. (2) Cross-section through first and second valvulae, at centre. (3) Egg (highly magnified). (4) Proximal end of first and second valvulae. (5) Ventro-lateral view of ovipositor and associated parts. (Diagrammatic). (6) Ventro-lateral view of ovipsoitor showing the insertion of important muscles. (Diagrammatic.) (7) Sagittal section of female abdomen showing poison gland, lubricating gland, and other accessory organs. (8) Poison reservoir and gland. (Highly enlarged.)

VIIT–IXT., Tergites ; *VIIS.*, subgenital plate ; *Ptgr.*, Proctiger ; *blb.*, Bulb ; 3*vl.*, 3rd valvulae ; 2*vl.*, 2nd valvulae ; 1*vl.*, 1st valvulae ; *Ovp.*, Ovipositor ; *Pcl.*, Poison canal ; *C. arm*, Central arm ; *R*1*vl.*, Ramus of the first valvulae ; *R*2*vl.*, Ramus of the second valvulae ; 1*st vlf.*, 1st valvifer ; 2*nd vlf.*, 2nd valvifer ; *R.ms.*, Ramus muscle ; 3*rd vlms.*, Muscle of the 3rd valvulae ; *F.ms.*, Muscle of the fercula ; *C.ms.*, Central muscle ; *OVY.*, Ovary ; *Spt.*, Spermatheca ; *rct.*, Rectum ; *lgl.*, Lubricating gland ; *P.dt.*, Poison duct ; *sp.*, Spiral ; *Res.*, Reservoir ; *P.gl.*, Poison gland ; *P.rs.*, Poison receptacle ; *Vl.*, Valve of poison receptacle.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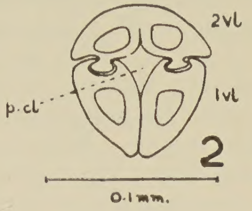
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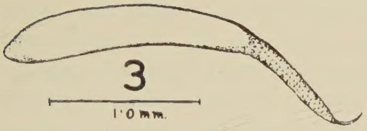
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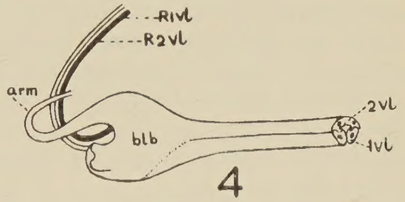
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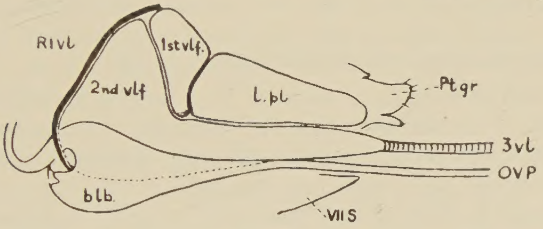
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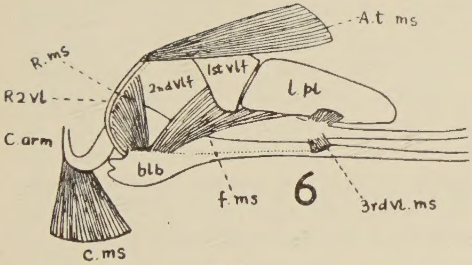
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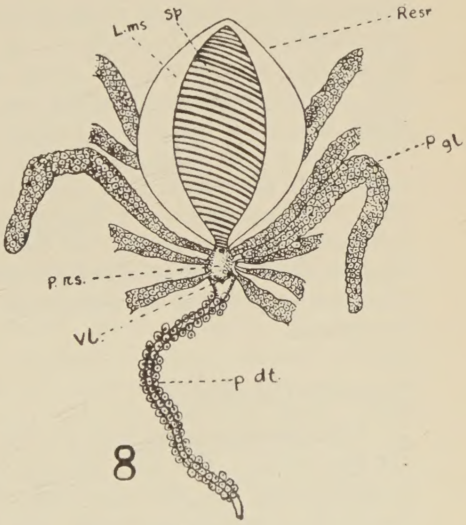
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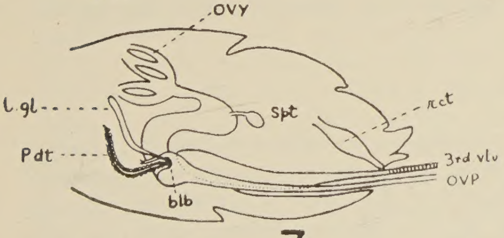
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7

up a position to start the attack. The wings are kept apart for a while, and raising itself on its hind legs, its abdomen is bent at right angles to the fore part of the body. The ovipositor tip is drawn up and down along the stem, and finally it is introduced into the borer tunnel. The ovipositor separates from the sheath, which curves in the form of a loop, and remains partly outside (Pl. I, fig. 1). With the help of the muscles in the abdomen the ovipositor is given a rotatory motion and the borer is located. If the parasite fails to locate the host, it withdraws the ovipositor and thrusts it in again from a different angle. When once the host is contacted, the parasite pushes its ovipositor deeper into the tunnel and, with the stylet which is now separated from the sheath, makes a lightning thrust into the body of the host. During this process the tip of the first valvulae, which is serrate and separated, extrudes beyond the second valvulae. Simultaneously the poison from the poison reservoir is injected into the body of the host. It then partly withdraws the stylet and waits for a few minutes. The host is found to wriggle and move away, but ultimately succumbs to the stabbing (Pl. I, fig. 1). Generally one stabbing is sufficient to paralyse the host, but in rare cases the parasite repeats the process until the host is completely paralysed. No particular region of the host body is preferred for stabbing. The sting marks can be made out as round fuscous spots.

Accessory Glands Associated with the Ovipositor.

The poison used in stinging is secreted by a large poison gland situated in the posterior part of the abdomen (fig. 8). Each gland is composed of 24 elongate lobes surrounding a central poison reservoir. Each lobe is about twice the length of the reservoir and opens into the bulb at the base of the reservoir. The reservoir is spindle-shaped and lined with a highly chitinised spiral (fig.8, *sp.*). The outer wall is very muscular and contains long muscles (fig. 8, *lms.*) which probably help in compressing the spiral, and eject the poison through the poison duct. The bulb at the base of the reservoir is provided with a circular valve below the openings of the poison secreting lobes (fig. 8, *vl.*). When the reservoir is full the valve remains closed, and probably opens when the spiral contracts to eject the venom. From the base of the reservoir runs a long duct surrounded by a large number of spherical cells. In addition to the poison gland there is a thin elongate gland which appears to be the " alkaline gland " of Snodgrass (1933). Both the poison duct and the lubricating gland open into the bulb of the second valvulae (fig. 7). The secretions of the lubricating gland probably serve to lubricate the joint of the first and second valvulae as well as the poison canal through which the egg has to descend.

Process of Oviposition.

After paralysing the host, the female parasite assumes a convenient position for egg laying. The hind legs are raised to the fullest extent, the ovipositor is thrust deep into the tunnel and the tip of the stylet is curved and brought under the paralysed caterpillar (Pl. I, fig. 2). The ovipositor sheath separates from the shaft and remains partly outside in the form of a loop. Just before the commencement of egg laying a regular and rhythmic movement of fluid can be noticed through the transparent sternite towards the vestibular cavity. The last three free abdominal segments are bent at an angle to the rest of the abdomen, the intersegmental membranes being stretched fully. The sub-genital plate is pulled along with the ovipositor shaft in a line with it, almost perpendicular to the abdomen. The membrane extending between the sub-genital plate and the proctiger is stretched to the maximum extent, and, due to the tension of the membrane, the ovipositor shaft remains erect and stiff, except at the distal end, which is curved and flexible. The first and second valvulae glide against each other in opposite directions, the movement of the latter being more pronounced than the former. The actual working of the valvulae can be clearly seen under a binocular microscope through the transparent intersegmental membranes. The egg is slowly pushed down the poison canal, compressed in the form of a thin strand, and the fluid secreted by the lubricating gland probably helps the egg to descend smoothly. As the egg descends, the valvulae work faster and faster until the body of the egg issues out of the ovipositor about two to three millimetres from the tip of the stylet. During this process the first and second valvulae remain joined, and the passage of the egg through the ovipositor cannot be seen. In any case, the egg traverses the entire distance of the ovipositor in a highly compressed state. The whole process takes about 30–35 seconds. The tip of the abdomen can be seen vibrating in unison with the movements of the valvulae when oviposition takes place. As soon as the egg is extruded, the chorion hardens quickly and the egg assumes its natural shape.

Mechanism of the Movement of the Ovipositor.

The basal mechanism of the genital plates brings about the forward and backward movements of the first and second valvulae of the ovipositor. This movement is brought about by the interaction of the two valvifers. A dorsal rotation of the anterior end of the second valvifer on the lower point of the first valvifer (fig. 5) causes the rotation of the first valvifer. This is brought about by a set of muscles connecting the second rami with the ninth tergite. The result of this rotatory movement is the gliding movement of the first and second valvulae in opposite directions, sliding on the rails. This movement helps the downward progress of the egg through the poison canal.

Muscles that Aid in the Movement of the Ovipositor.

The important muscles that are connected with the ovipositor are the anterior tergal muscle of the second valvifer, the muscles of the furcula and the ramus muscle of the second valvulae (fig. 6, *A.t.ms.*, *F.ms.*, *R.ms.*). The muscles of the furcula are highly developed and composed of a large number of fibres. They arise on the inner surface of the second valvifer and are inserted on the dorsal margin of the bulb where the second pair of valvulae are fused. Their action appears to deflect the distal ends of the ovipositor shaft since their contraction can cause the movement in one direction only. The ramus muscle of the second valvulae is a relatively large muscle and is stretched in between the two ends of the ramus of the second valvulae. There is a strong band of muscle fibres arising from the central arm (fig. 6, *C.ms.*) and inserted at the base of the seventh sternite. In addition to the above muscles, there is also another set of small muscles near the posterior end of the second valvifer (fig. 6, *3rd vl. ms.*) which probably assist in the manipulation of the third valvulae or sheath.

It is suggested that as a result of the combined action of the ramus muscle of the second valvulae and the anterior tergal muscles of the second valvifer, the second valvifer is made to rotate, thereby causing the rotation of the first valvifer. The alternate movement of these muscles is responsible for the opposite movements of the first and second pair of valvulae constituting the ovipositor. The up and down and the side movements of the ovipositor are controlled to a large extent by the muscles of the furcula and the central band of muscles.

Discussion.

The morphology of the genitalia and the muscles that operate the ovipositor in typical forms of most of the Orders of insects have been described in detail by Snodgrass (1933). The manner of oviposition of the species attacking wood boring larvae has attracted much attention, but there are only a few papers dealing with the mechanism of oviposition in those species which do not use their ovipositor for drilling. The important papers dealing with the process of oviposition in parasitic hymenoptera have been reviewed by Clausen (1940). Abbot (1934) has described and figured in detail the mechanics of oviposition in *Megarhyssa lunator F.*, a parasite which bores into wood. Recently Bender (1943) has described the genitalia and the associated parts of the female reproductive organs in the braconid *Habrobracon juglandis*, but he has not studied the process of oviposition.

The structure of the ovipositor and the accessory organs of the sex apparatus in *Stenobracon* agrees more or less with the descriptions given by Snodgrass and Bender. In *Stenobracon* the joint of the first and second pair of valvulae is quite different in construction. The rails of the second valvulae are flattened at the sides and fit into the grooves of the first in the pattern of a dovetail joint and the two pairs of valvulae cannot be separated. A similar arrangement has been noticed by us in the case of the parasite, *Bracon gelechiae.* In the case of *Habrobracon* studied by Bender, the sides of the rails are not flattened. The manner of oviposition in *Stenobracon deesae* is very interesting. Clausen (1940) observes that in all species having the pedicellate type of eggs, only the pedicel is held within the channel of the ovipositor, and the main body issues ventrally at the base of the ovipositor immediately after it leaves the oviduct. Detailed observations carried out in the laboratory have shown that the pedicellate egg of *Stenobracon* descends the poison canal in a compressed state, and the main body of the egg is visible to the outside only when it reaches the tip of the ovipositor. The egg, which is about 0·3 mm. in diameter, has to pass through the narrow poison canal having a diameter of about 0·03 mm.

The structure of the poison gland in *Stenobracon* shows certain deviations. The bulb at the base of the reservoir is provided with a valve which apparently remains closed when the reservoir is full of venom, but opens out under pressure when the spiral of the reservoir contracts. It may also serve to prevent the poison running down the canal from the bulb, when the poison glands pour their secretions. In the case of *Stenobracon* the so-called " alkaline gland " of Snodgrass probably secretes an oily liquid which serves to lubricate the valvulae joint and the ovipositor canal (Wigglesworth, 1947). The exact nature and function of the spherical cells associated with the poison duct is not understood. Bender considers the secretions of these cells to add to the venom of the poison glands. We, however, think that the secretions of the spherical cells may probably help in keeping the chorion of the egg moist and soft during its descent through the ovipositor canal.

The muscles that operate the ovipositor are the anterior tergal muscle, the muscles of the furcula, the ramus muscle of the second valvulae, and the central band of muscle. Snodgrass (1933) has described in the case of the queen bee two more important sets of muscles, viz., the posterior tergal muscle of the second valvifer and the tergo-valvifer muscle, which aid in the process of oviposition in the bee.

SUMMARY.

The paper deals with the structure of the ovipositor and the accessory organs, and the process of oviposition in *Stenobracon deesae* (Cam.), an ectophagous larval parasite of the lepidopterous borers of sugarcane and maize in India.

The ovipositor is composed of three pairs of valvulae. In life, the third pair, which is the only pair visible, ensheath the ovipositor shaft between their hollowed surfaces. The ovipositor shaft is composed of the first and second pairs of valvulae, which are joined in such a way to form a canal between them. The second valvulae are provided with a pair of rails which fit into the grooves of the first valvulae to form a dove-tail joint. The canal running through the ovipositor serves as a passage for the egg as well as the poison used in stinging. The poison is secreted by a large poison gland situated in the posterior part of the abdomen. Each gland is composed of 24 elongate lobes surrounding a central poison reservoir, which is spindle-shaped and lined with a chitinised spiral. The bulb at the base of the reservoir is provided with a circular valve which normally remains closed, but opens when the spiral contracts to eject the poison. In addition, there is a thin elongate gland (alkaline gland) whose secretions probably serve to lubricate the poison canal and the joints of the first and second valvulae. The secretions of the spherical cells associated with the poison duct probably help in keeping the chorion of the egg moist and soft during its descent through the ovipositor canal.

The process of stabbing and oviposition is described in some detail. While ovipositing, the first and second valvulae glide against each other in opposite directions and the egg is pushed down the poison canal in a highly compressed state. The basal mechanism of the genital plates brings about the forward and backward movements of the first and second valvulae of the ovipositor. These movements are controlled by a set of muscles. The important muscles that are connected with the ovipositor are the anterior tergal muscles of the second valvifer, the muscles of the furcula and the ramus of the second valvulae. It is suggested that as a result of the combined action of the ramus muscle of the second valvulae and the anterior tergal muscle of the second valvifer, the second valvifer is made to rotate, thereby causing the rotation of the first valvifer. The alternate movements of these muscles is responsible for the

opposite movements of the first and second pair of valvulae constituting the ovipositor.

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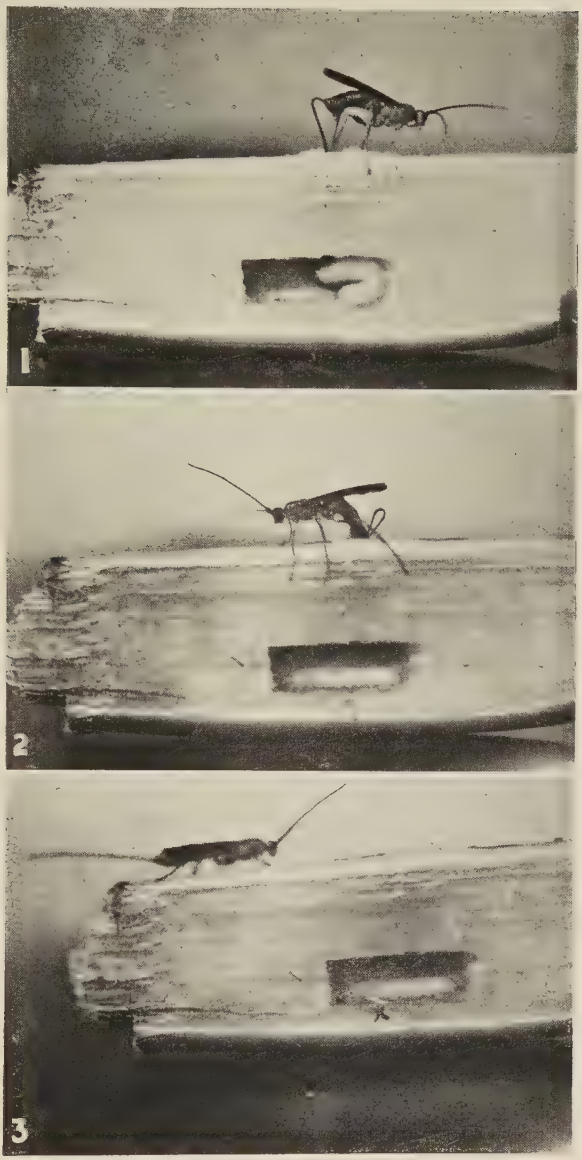
PLATE I.

FIG. 1.—Female *Stenobracon* with ovipositor partially withdrawn after stinging the host, prior to oviposition. The caterpillar is wriggling as a result of stabbing. (Natural size.)

FIG. 2.—The same female in the act of oviposition. The abdomen is thrust into the cane stem and the tip of the stylet is brought below the paralysed caterpillar. The ovipositor sheath remains outside. (Natural size.)

FIG. 3.—The same female resting after ovipositing. The glistening white egg is laid below the larva (*x*). (Natural size.)

Proc. R. ent. Soc. Lond. (A). *Vol.* 29. PLATE 1.



Oviposition in *Stenobracon deesae.*

T. V. Venkatraman and B. R. Subba Rao.

Adlard & Son, Ltd., Dorking.

WING VENATION AND MALE GENITALIA OF *TESSARATOMA* BERTHOLD,[1] WITH REMARKS ON TESSARATOMINAE STÅL[1] (HEMIPTERA : PENTATOMIDAE).

By D. Leston, F.R.E.S.

Introduction.

Work in progress upon the Ethiopian and Oriental Pentatomoidea has indicated that the Tessaratominae occupy a pre-eminent place in the phylogeny and classification of the superfamily, a place, however, that can only be elucidated after examination of many genera. It has been thought advisable to present details of *Tessaratoma* now and to draw attention to the features which point to its primitive nature.

Wing Venation.

Leston (1953*a*) has proposed a system of nomenclature and interpretation for the wings of Acanthosomidae and subsequently (1953*b*) applies it to the Phloeidae. Fig. 1 shows the right wing of *Tessaratoma papillosa* (Drury) with the venation lettered in accordance with this scheme. Sc, present as a short trachea in the larval wing, is represented only by a short stub at the base of the primary vein. The primary vein is strongly sclerotic, bi-convex, and formed by R + M. The trachea M departs from the vein and crosses over to Cu. Part of this crossing over is unrepresented by a vein (shown dotted in the figure) and part by the spur usually referred to as the hamus. This departure of M from the primary vein to join Cu is typical of all Pentatomoidea and Coreoidea. R continues on from R + M almost to the wing margin; the caesura is well marked and a short, atracheate, coupling stigma connects it to the marginal couple. The trachea R passes through the caesura and can be clearly seen under high-power.

Cu + M divides, as in all Pentatomoidea, once more and M bends forwards then outwards, thus following closely the larval tracheation. The subsequent course of Cu also follows that of its relevant trachea; it is joined by a short, atracheate, antevannal vein.

The bifid vannal fold encloses the atracheate intervannals, Iv and Iv″, and behind the posterior vannal fold the venation and folds are of the usual Pentatomoid-Coreoid form.

Male Genitalia.

The eighth, or pregenital, segment is complete, although reduced in size. The lateral sutural area is well defined, and a distinct tergum, although somewhat asclerotised medially, is present. The spiracles are not at all reduced,

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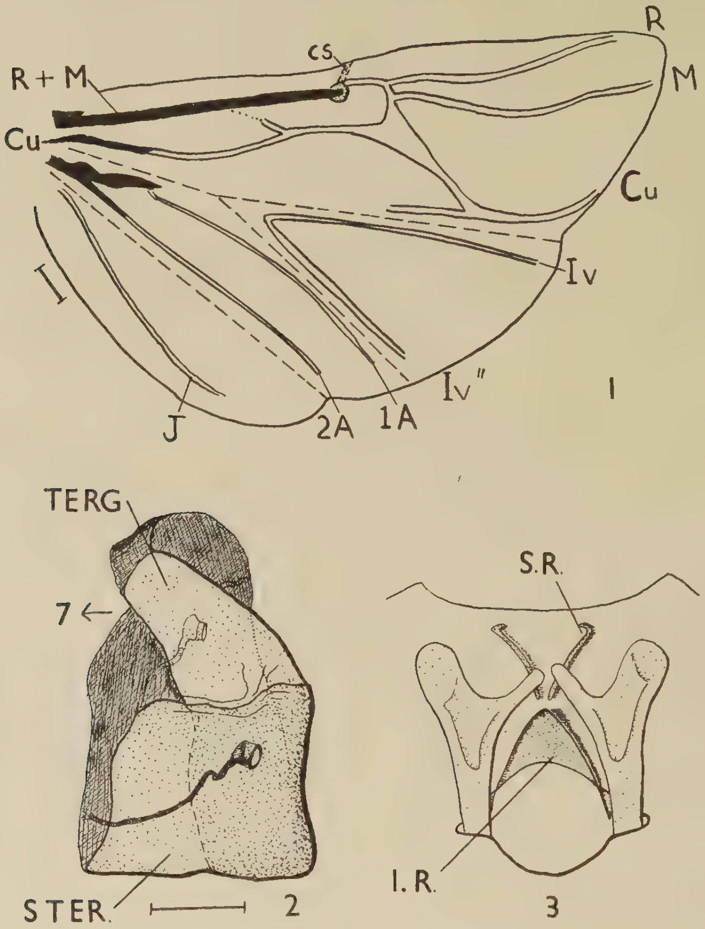
[1] Since this paper was prepared, new recommendations have appeared regarding the authorship of group names (1953, *Copenhagen Decisions on Zoological Nomenclature*. London). The family group-name based on *Tessaratoma* must be credited to Schilling (1829, *Beitr. Ent., Breslau* **1** : 34–92).

being indistinguishable from those of preceeding segments, and are supplied with tracheae and an occluding apparatus.

The ninth segment is of the usual Pentatomoid form. The inside of the ventro-caudal margin (fig. 3) is marked by the presence of aedeagal rests or



Figs. 1–3.—*Tessaratoma papillosa* (Dru.). (1) Right wing. (Scale = 1·0 mm.) (2) Eighth male segment. TERG, tergum; STER, sternum. (Scale = 1·0 mm.) (3) Inner aspect of hypandrium with aedeagus removed. S.R., superior rests; I.R., inferior rest. (Somewhat diagrammatic.)

supports. These structures were first noted in Phloeidae (Leston, 1953*b*) and have also been detected in Pentatominae (Leston, 1953*c*); they are probably present in most Pentatomoidea and are essentially merely outgrowths of the inner wall, itself, as indicated by Baker (1931), the inturned posterior margin of the ninth sternum. The genital atrium is delimited at its base by the ninth–tenth intersegmental membrane; the parameres arise beneath the floor of the atrium each side of the aedeagus. In *Tessaratoma* the general structure of the atrium and parameres follows the usual Pentatomoid plan.

The aedeagus (figs. 4 and 5) was figured and described by Pruthi (1925). The theca is well sclerotised and the endosoma is apparently, even in repose, somewhat everted. This is of interest as the true Scutellerinae have been shown (Leston, 1952) to possess a non-retractible endosoma, whilst in Pentatominae and Amyotinae (Asopinae *auctt.*) the endosoma always retracts completely within the theca.

The seminal duct takes a complex course. It curves back on itself at a point some considerable way alongside (but not within) the vesica and enters the reservoir at a point mid-way between the bases of the first conjunctival appendages. The reservoir is apparently bicameral medially (probably so in all Pentatomoidea) and narrows apically to form an elongate, densely sclerotic vesica. The vesica is sleeved in a median projection of membranous conjunctiva.

The conjunctival appendages are all paired, save the median, vesica-enveloping process, mentioned above. The first pair are short and sclerotic but desclerotise somewhat at their origin. The second pair arise from the same side of the vesica as the first and they are long, inflatable and membraneous ; they are inwardly and towards the vesica slightly bifid. The third pair are dorsal, arise close to each other and are sclerotic with their apices deeply emarginate.

OTHER MORPHOLOGICAL FEATURES.

In certain features, *Tessaratoma* departs from the strictly Pentatomoid form. The rostrum is short and scarcely reaches to the level of the anterior coxae, whilst the bucculae too are short : these features are common to Phyllocephalinae and Dinidorinae and very different from Pentatomini and most other Pentatominae. In fact, this short rostrum and bucculae are remarkably similar to those of many Coreidae.

The second abdominal segment is noteworthy for the fact that the spiracles are always exposed : this character was the principal one upon which Stål diagnosed the group. Now, in Pentatominae, with scarcely an exception save in certain genera probably erroneously placed in this group (e.g., *Boerias* Kirkaldy), the second spiracle is always hidden beneath the metapleuron and one can but conclude that the Pentatominae are thus more evolved than Tessaratominae. Dollo's Law precludes the reacquisition of visible spiracles and thus it is concluded that Pentatominae have evolved further, at least in this character, than have Tessaratominae.

THE STATUS OF TESSARATOMINAE.

Certain groups placed heretofore in Tessaratominae are doubtfully so placed, and Natalicolini has already been removed from the group and accorded subfamily status (Leston, 1953*c*). Natalicolinae have two-segmented tarsi and male genitalia indistinguishable from Pentatominae, but the second abdominal spiracle is exposed and the rostrum short. Thus it is to be understood that the following discussion of Tessaratominae refers to Tessaratomini and Eusthenini. It has been found impossible to homologise the genitalia of Tessara-

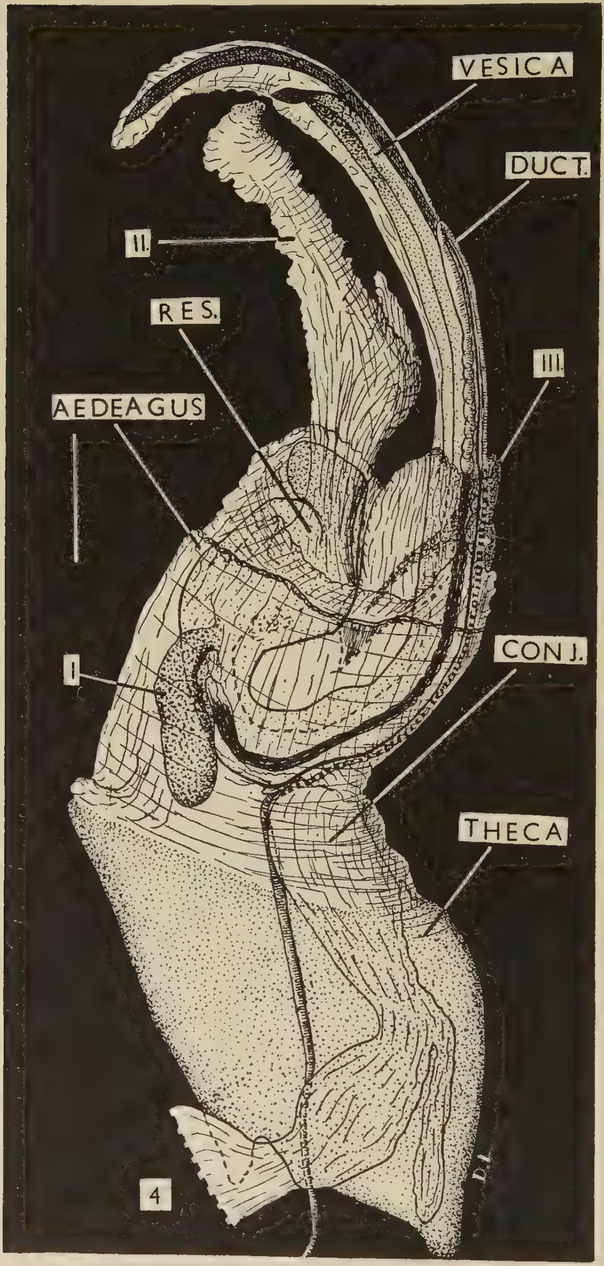


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FIG. 4.—*Tessaratoma papillosa* (Dru.). Aedeagus, expanded, lateral. i, ii, iii, first, second and third conjunctival appendages. RES, reservoir; CONJ, conjunctiva; DUCT, ductus seminis. (Scale = 0·5 mm.)

tominae with those of Pentatominae ; the entire structure of the conjunctival appendages and theca clearly differentiates the former from all other subfamilies of Pentatomoidea. Pruthi (*op. cit.*) came to the same conclusion, but unfortunately stated that the same genitalia were found in Dinidorinae. It is clear that he had examined no Dinidorinae, for he names none as having been seen (a similar mis-statement occurs in his paper concerning Discocephalinae). The male genitalia of Dinidorinae are very different from those of Tessaratominae and have been described elsewhere (Leston, 1953*d*).

If we bear in mind the degree of sclerotisation of the three pairs of conjunctival appendages it soon becomes apparent that the nearest approach to the Tessaratominine aedeagus is to be found in Scutellerinae. This similarity has not previously been noticed, because almost all work on the Scutellerinae has been confined to the European genera, especially *Eurygaster* Laporte. However, the genitalia of many Scutellerini have now been examined and figured (Leston, 1952) and, as a consequence, the Palaearctic and Nearctic genera previously placed in Scutellerinae were removed and placed temporarily in Pachycorini and Eurygastrini (the latter has since been raised to sub-family status within Pentatomidae by Leston, 1953*e*). Some true Scutellerinae were examined by Pruthi (*Lampromicra* Stål, *Chrysocoris* Hahn, *Scutellera* Lamarck and *Cantao* Amyot & Serville) who correctly noted that their male genitalia are unlike those of the Pentatominae.

Comparison of the two subfamilies, Tessaratominae and Scutellerinae, reveals the following similarities :

(1) The dorsal conjunctival appendages, (third), are usually short and always sclerotic.

(2) The seminal duct is always dorsal.

(3) The canal at the junction of theca and reservoir is always somewhat undulating.

(4) The reservoir and vesica merge imperceptibly one into the other.

(5) The second conjunctival appendages are always ventral of the vesica and always membranous (these were styled first conjunctival appendages by Pruthi, and Leston, (1952).

(6) The first conjunctival appendages are always ventral and sclerotic.

Taken by itself, this similarity of the male genitalia could perhaps be considered as no more important than any other single character and it is well known that in external appearance Scutellerinae, with their large, often metallic coloured scutellum, are very different from Tessaratominae. However, similarity also exists between the two subfamilies in the wing venation. Stål (1872) diagnosed Scutellerinae principally on wing venation and wrote " Venis primaria et subtensa alarum distantibus, aream medio latiorem includentibus ; hamo alarum obvio ; . . ." Examination of fig. 1 shows the venation of *Tessaratoma* to fit this diagnosis, whilst it is well known that in Pentatominae, Podopinae and most other Pentatomidae R + M and Cu are close together and parallel and a hamus is usually absent (save in Strachini, which is probably a good subfamily that should be removed from Pentatominae).

Examination of the male genitalia and wing venation of a great many Pentatomoidea shows that both provide good phylogenetic evidence. Recent work on Phloeidae (Leston, 1953*b*) supports this. In Phloeidae, the eighth male segment is complete with sclerotised tergum and functional, occluding

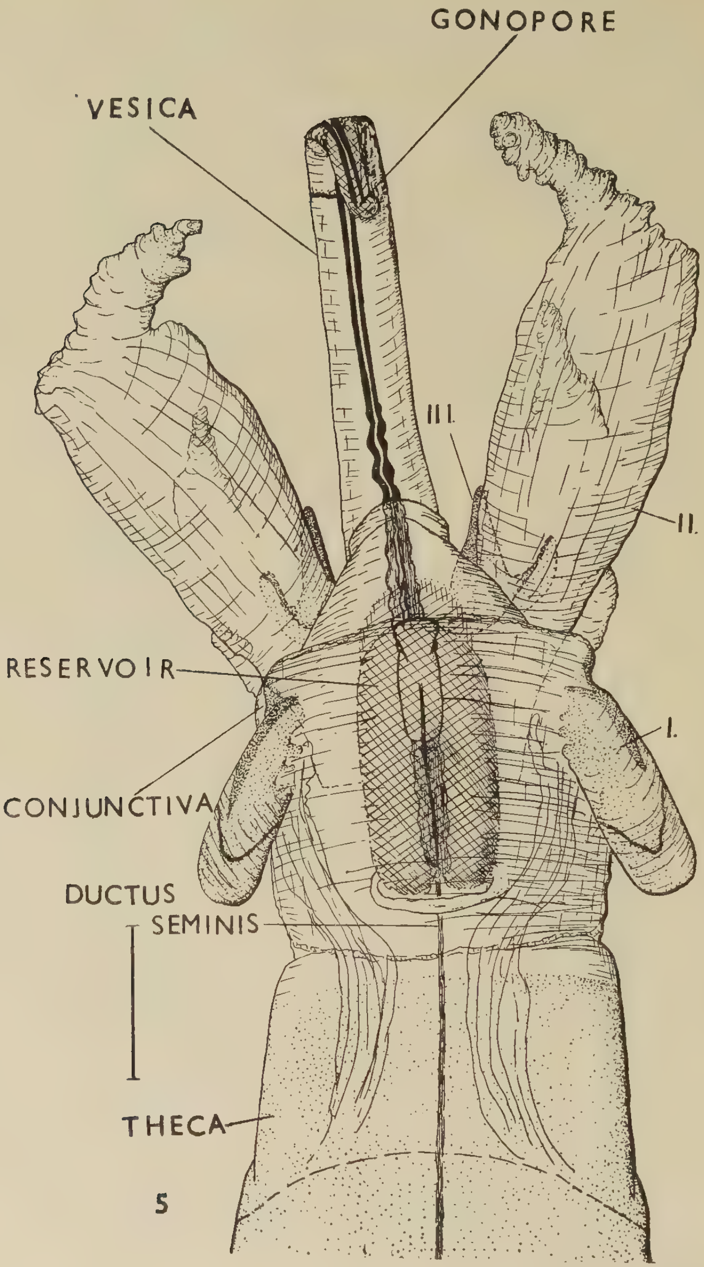

Fig. 5.—*Tessaratoma papillosa* (Dru.). Aedeagus, ventral, expanded. Basal area omitted. (Scale = 0·5 mm.)

and tracheate spiracles; the second abdominal spiracles are visible, the metapleural suture coincident with the visible posterior metapleural margin: these known primitive characters would alone suffice to relate Phloeidae with the similarly primitive Tessaratominae. But, in addition, Phloeidae has an identical wing venation and an aedeagus that, although modified, can nevertheless be homologised without difficulty with that of Tessaratominae.

The venation and genitalia of Podopinae have been discussed, along with other morphological features (spermatheca, eighth male segment, etc.) elsewhere (Leston, 1953*f*). Although placed by Poisson (1951) along with Scutellerinae in a single subfamily it is remote from both it and Tessaratominae: in all respects Podopinae (which does *not* include *Graphosoma* Laporte) is close to Pentatominae.

Kirkaldy (1909) concluded that forms without a hamus are more evolved than forms with one, and he also grouped Phloeidae and Scutellerinae together apart from Pentatominae on venational characters. He thus anticipated the present writer's findings.

CONCLUSIONS.

(1) The venation of Phloeidae, Scutellerinae (Scutellerini + Elvisurini + Sphaerocorini *auctt.*) and Tessaratominae (Tessaratomini + Eusthenini) is identical and differs from Pentatominae in R + M and Cu being parallel almost throughout, and in a hamus being present.

(2) The aedeagus in Tessaratominae, Scutellerinae and Phloeidae is derived from a single source characterised by the presence of three pairs of conjunctival appendages with the third pair invariably sclerotic. The aedeagus of Pentatominae, Amyotinae, Podopinae and Eurygastrinae has much in common, but is far more evolved and reduced than in the previously mentioned groups; it is derived from this former group.

(3) Whereas the eighth male segment has retained its functional tracheation, distinct sternum and tergum, in Phloeidae and Tessaratominae, in Podopinae, Scutellerinae, Eurygastrinae, Amyotinae and Pentatominae this segment has degenerated to become a thin ring with non-functioning spiracles and loss of identity of the tergum.

(4) The visibility of the second abdominal spiracles of Phloeidae and Tessaratominae is the primitive state in Pentatomoidea; in the majority of the remaining groups these spiracles have become covered by the metapleura.

(5) The aedeagus of Tessaratominae, the position and shape of the thoracic gland openings, the short rostrum and bucculae suggest a connection with the Coreoidea (but this requires investigating further from the Coreoid side).

ACKNOWLEDGMENTS.

The Trustees have permitted examination of the collections of the British Museum (Natural History): Dr. W. E. China, of the same institution, has assisted me greatly, more especially in investigation of tracheation in *Tessaratoma*.

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REPORT ON CORIXIDAE (HEMIPTERA) TAKEN IN LIGHT-TRAPS AT ROTHAMSTED EXPERIMENTAL STATION.

By E. S. Brown, B.A., F.R.E.S.
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Continuous use of light-traps at Rothamsted Experimental Station, Harpenden (Hertfordshire), from 1946–1950, culminated in a special experiment in August and September of the last of these four years, with results so interesting in the family Corixidae that publication of a short account of them is desirable. I am deeply indebted to Dr. C. B. Williams for permission to use these data, and to Mr. T. R. E. Southwood for sorting out the Corixidae from the other insects in the collections.

An account of the Hemiptera–Heteroptera taken in Rothamsted light-traps in a previous series of observations, during the period 1933–1937, is given by Thomas (1938). Out of a total of 1486 Heteroptera he records only 42 Corixidae, and in over half of these the species could not be determined. A description of the trap used in these earlier experiments is given by Williams (1948). An ordinary electric light of 300 candle-power was used. This type of trap will be referred to as the "Rothamsted trap." An identical trap, with the same light, was used in all the first part (1946–49) of the more recent series of experiments, and during these years only 12 Corixidae were taken in all. During a limited period of the last year (1950), however, a Robinson-type trap with a mercury vapour lamp was used; the number of Corixidae taken during this period was incomparably greater than hitherto, for in about one month no less than 1253 were caught; of this number 97·7 per cent. were taken in five (non-consecutive) nights, and over half (59·1 per cent.) on one of these nights. This fact alone is sufficiently remarkable to justify analysis of the results.

The various traps and their locations during the whole 1946-1950 period are as follows: each trap is denoted by reference-letters which are used elsewhere in this paper. Their position is shown on the accompanying map.

Traps T, Tm and R, representing three different combinations of type of trap and type of light, were employed in a special "rotation experiment" to compare their achievements (see Williams, 1951). Three stations were selected in the woodland at Rothamsted Manor (marked 1, 2, 3 on the map), and the three traps set one at each station. The following night, each trap was moved round to one of the other stations, and this procedure was repeated nightly from 16th–31st August (15 days), so that each of the three types of combination was employed five times at each of the three stations. The object of this was to eliminate spurious results due to differences in visibility of the light or in other factors at the three stations. The results, expressed as the total number of Corixids caught in each type of trap, were as follows:

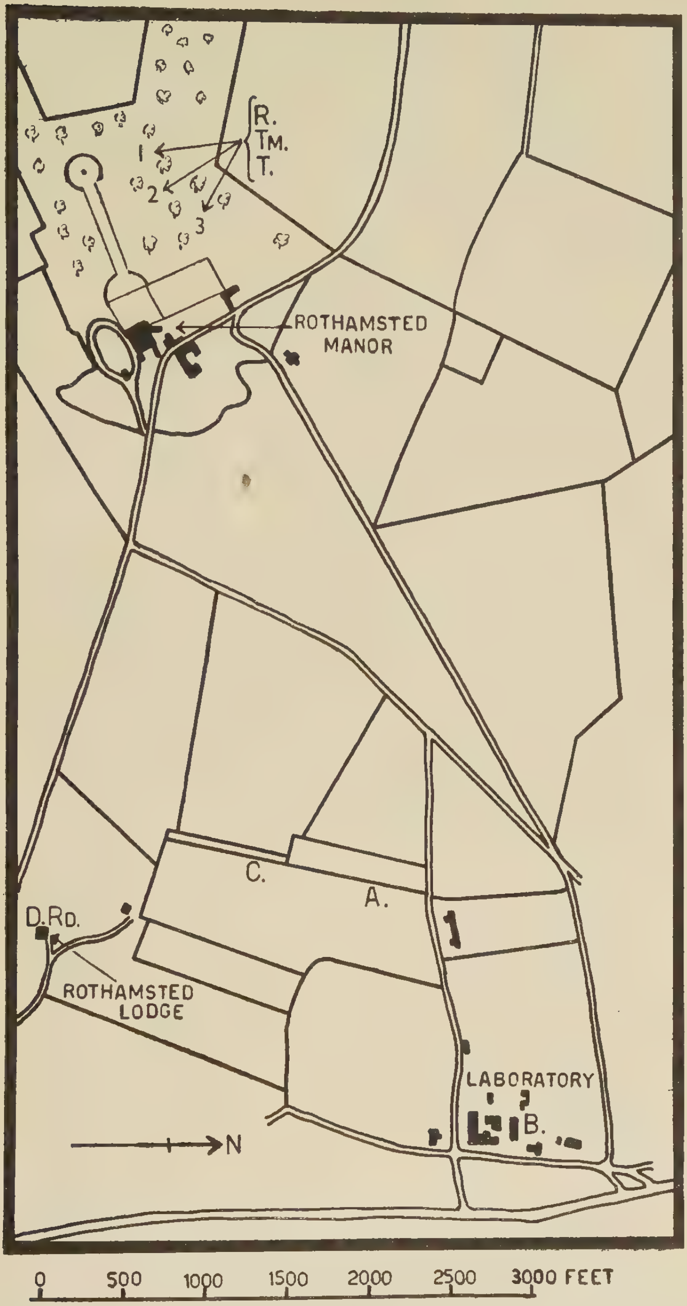
Reference letters of trap . .	T	Tm	R
Type of trap	Rothamsted	Rothamsted	Robinson
Light	Normal	Mercury vapour	Mercury vapour
Number of Corixidae caught .	1	5	755

Type of trap.	Light.	Location.	Period of use.	Reference letters.
Rothamsted	Normal	On side of field, Rothamsted Farm	1932–37 and 1946–49	A
		Top of exposed building, Rothamsted Laboratory	1946–49	B
		Another part of same field as A	1946–47	C
		In garden of Rothamsted Lodge	1948–49	D
		In woodland, Rothamsted Manor	1950 16th–31st August only	T
	Mercury vapour	In woodland, Rothamsted Manor		Tm
Robinson	Mercury vapour	In woodland, Rothamsted Manor		R
		In garden of Rothamsted Lodge	1950, 3rd–7th and 9th–14th August	RD

These figures suggest strongly that the mercury vapour lamp attracts more Corixidae than an ordinary lamp, and even more strongly that the Robinson trap is more effective than the Rothamsted. This conclusion is supported by the results from the Trap RD (also a Robinson trap with mercury vapour lighting), which was run nightly at Rothamsted Lodge from 3rd–7th and 9th–14th August, and caught a total of 492 Corixidae during this period of 11 days, compared with only a single individual caught in Trap D, kept running nightly in the same spot in 1948–49. Although a fourth possible combination —a Robinson trap with normal lighting—was not used, it is fairly safe to infer that the design of the Robinson-type trap is the important factor for Corixidae. The difference is probably due to the absence of a roof in the Robinson trap which allows the light to be visible from above.

In this connection it is of interest to compare the catches of Corixidae with those of other (terrestrial) Hemiptera-Heteroptera; the figures for the period of the rotation experiment (16th–31st August, 1950) provide a little evidence. In trap R (Robinson-type) 755 Corixidae were taken, of which 748 came on 21st August; as regards the Rothamsted-type traps, there were only 5 in Trap Tm (of which 4 were on 21st August), and only 1 in Trap T (on 22nd August). During this same period the Robinson trap also caught more terrestrial Hemiptera than the two Rothamsted traps combined, but the difference (25 as compared with 13) was not nearly so great as in the case of the Corixidae; but then in the latter the difference is due almost entirely to the large catch on one night (21st August), the maximum for other Heteroptera being on a different night (20th August).

These differences are doubtless due to the nature of the autumn migration in Corixidae, which mostly reach the adult stage together in large numbers in



Map showing positions of the various traps used at Rothamsted which are mentioned in this paper. 1, 2, 3, positions of traps T, Tm and R in the "Rotation experiment."

any one habitat; as flightless nymphs they have been confined to their ponds or other habitats during the summer, but with the development of wings mass emigrations of an "explosive" nature occur; it so happens that the rotation experiment was operating at about the time of year when such emigrations occur, so that there were plenty in the air to be attracted to a suitable trap. Migrating Corixidae are attracted down to earth by any shining objects which suggest light reflected from water, even by such things as the roofs of saloon cars or greenhouses; they might well be deceived, therefore, by the Robinson trap which allows the light to go upwards.

Corixidae have two main migration periods during the year. One is in spring, when overwintered adults migrate extensively; the other is in late summer and autumn, when the new generation reaches the imaginal state. The first appears to function as a means of ensuring even distribution of each species in suitable habitats prior to egg-laying; an analysis of some relevant observations has appeared in a previous paper (Brown, 1951), in which it was shown that species differ in their rates of migration. The autumn migration undoubtedly functions largely as a relief of the high population densities which result in individual habitats from large numbers of nymphs reaching the adult stage at more or less the same time. One tends therefore to get mass emigrations from individual habitats of the particular species (often only one or two) which are dominant in them. This is reflected to a large extent in the light trap catches, all of which occurred in late July and throughout August; these catches are analysed in Table I, and it can readily be seen that each of the largest catches is made up principally of one or two species, except possibly that on 6th August, when five or six species were moderately well represented.

The total numbers of each species taken do not indicate the same relative migration-rates as those deduced from analysis of spring migrations. For comparison, the relative spring migration-rates as given by Brown (1951) for certain species are set out below, together with the total numbers of the species taken in light-traps; the two series are each arranged in descending order:

Order of spring migration rate.	Order of numbers taken in light-traps.
Sigara nigrolineata.	*Callicorixa praeusta.*
S. lateralis.	*Sigara striata.*
Callicorixa praeusta.	*S. falleni.*
Corixa punctata.	*S. concinna.*
Hesperocorixa sahlbergi.	*S. lateralis.*
H. moesta.	*Hesperocorixa sahlbergi.*
Sigara falleni.	*Corixa punctata.*
S. striata.	*Sigara nigrolineata.*
	S. fossarum.
	Hesperocorixa linnei.
	H. moesta.

In the light-trap catches, there are large numbers of *Sigara striata* and *S. falleni*, which do not as a rule migrate freely, while such ready migrants as *S. lateralis*, *S. nigrolineata* and *Corixa punctata* do not figure prominently. But one would hardly expect a close agreement on account of the nature of the autumn migration, during which high population densities may stimulate almost any species to emigrate *en masse*, and it is largely a matter of chance

TABLE I.—*Details of the Corixidae caught in Light-traps at Rothamsted from* 1946–1950. *Males and females are shown separately, the numbers of males on the left, and of females on the right of the colon.*

Date.	Trap.	*praeusta.*	*striata.*	*falleni.*	*concinna.*	*lateralis.*	*sahlbergi.*	*distincta.*	*punctata.*	*nigrolineata.*	*fossarum.*	*linnei.*	*moesta.*	Total.
1946														
23·vii	B	0 : 1	—	—	—	—	—	—	—	—	—	—	—	1
4·viii	A	—	—	—	—	—	—	—	0 : 1	—	—	—	—	1
1947														
26·vii	B	—	—	—	1 : 0	—	—	—	—	—	—	—	—	1
15·viii	C	—	—	0 : 1	—	—	—	—	—	—	—	—	—	1
1949														
26·vii	B	—	—	—	—	—	—	1 : 0	—	—	—	—	—	1
29·viii	A	—	—	—	1 : 1	—	—	—	—	—	—	—	—	2
	B	0 : 2	—	—	1 : 1	—	—	—	—	—	—	—	—	4
	D	—	—	—	1 : 0	—	—	—	—	—	—	—	—	1
1950														
4·viii	RD	16 : 7	0 : 1	—	3 : 3	—	—	—	—	—	—	—	—	30
6·viii	RD	13 : 16	27 : 23	62 : 46	10 : 4	6 : 8	1 : 7	0 : 1	—	1 : 0	0 : 1	0 : 1	0 : 1	228
7·viii	RD	15 : 27	3 : 2	0 : 2	6 : 6	0 : 1	1 : 0	0 : 1	2 : 0	—	—	—	—	66
8·viii	RD	0 : 1	—	—	—	—	—	—	—	—	—	—	—	1
10·viii	RD	0 : 1	—	—	—	—	—	—	—	—	—	—	—	1
13·viii	RD	75 : 84	3: 2	—	—	—	—	—	—	—	—	—	—	164
14·viii	RD	1 : 1	—	—	—	—	—	—	—	—	—	—	—	2
20·viii	RE	—	1 : 1	—	—	—	—	—	—	—	—	—	—	2
21·viii	Tm	2: 2	—	—	—	—	—	—	—	—	—	—	—	4
	RE	347 : 311	30 : 57	—	—	1 : 0	0: 2	—	—	—	—	—	—	748
22·viii	T	0 : 1	—	—	—	—	—	—	—	—	—	—	—	1
	RE	0 : 3	—	—	—	—	—	—	—	—	—	—	—	3
23·viii	RE	0 : 1	—	—	—	—	—	—	—	—	—	—	—	1
28·viii	Tm	1: 0	—	—	—	—	—	—	—	—	—	—	—	1
31·viii	RE	—	—	1 : 0	—	—	—	—	—	—	—	—	—	1
Totals by sexes (male : female)		470 : 458	64 : 86	63 : 49	23 : 15	7 : 9	2 : 9	1 : 2	2 : 1	1 : 0	0 : 1	0 : 1	0 : 1	633 : 632
Grand totals		928	150	112	38	16	11	3	3	1	1	1	1	1265

whether a light-trap happens to be suitably placed to attract an emigration swarm from some local habitat. *Callicorixa praeusta*, however, which was represented in traps over twice as frequently as any other species, and by a total number of individuals nearly three times that of all the other species put together, is well known to be a ready migrant, and is high up in the spring list also. Incidentally, there can be little doubt that the *Callicorixa wollastoni* D. and S. recorded from Rothamsted light-traps by Thomas (1938) should be referred to this species, for *C. wollastoni* probably does not occur within two or three hundred miles and certainly did not occur in the collections dealt with in the present paper.

A point of considerable interest is the sex-ratio of migrating Corixidae. Table I shows that for all species taken together the sexes are equally represented (633 males and 632 females); as far as individual species are concerned, the only species represented by significant figures were *Callicorixa praeusta* (470 males, 458 females), *Sigara striata* (64 males, 86 females), *S. falleni* (63 males, 49 females), and *S. concinna* (23 males, 15 females), and in none of these does the ratio deviate significantly from equality; χ^2 tests give values of 0·155, 3·227, 1·75 and 1·684 respectively, all less than the accepted value of 3·841 for significant deviation. This is interesting in the light of hitherto unpublished observations on spring migrants, where the ratio may be very one-sided. Such deviations are probably due to differential survival-rate of the sexes over the winter, rather than to differences in their migration-rate.

In autumn, with a freshly emerged adult population, one would expect the sexes to be more nearly equally represented, and one finds from the data given above that they migrate in approximately equal numbers.

SUMMARY

1. An account is given of the Corixidae taken in light-traps at Rothamsted Experimental Station during the years 1946–1950.

2. The number of Corixidae taken was small until 1950, when a Robinson type light-trap with mercury vapour lighting was used over a limited period and some very large catches of Corixidae resulted.

3. A rotation experiment, in which different combinations of types of trap and of lighting were used at three points in rotation, indicates that the Robinson type trap is particularly attractive to Corixidae.

4. The conclusion is reached that the large catches were due not only to the nature of the Robinson trap, but to the fact that its use coincided with the period of the autumn migration, when the new generation reaches the adult stage and emigrates from the breeding habitats in large numbers.

5. The catches were analysed specifically, and as regards sex-ratio, and are compared with previous observations on the composition of spring migrations. Certain interesting differences are discussed.

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THE POST-EMBRYONIC DEVELOPMENT OF THE FLIGHT MUSCLES OF *LAMARCKIANA* SP. (ORTHOPTERA) AND A BRIEF COMPARISON OF THESE WITH THOSE OF *SAUSSUREA STUHLMANNIANA* (KARSCH) AND *TANITA DISPAR* (MILLER).

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Introduction

A number of Acrididae have fully winged males while the females of the same species are either apterous or have relatively shorter wings than the males. A comparison of the flight muscles of the adults of some of these species has already been made : La Greca (1945, 1947) gave a brief account of some and Thomas (1952, 1953) gave a more detailed comparison of those of *Lamarckiana* sp., an African pamphagine, and of *Chorthippus parallelus* (Zett.), a British member of the Acridinae. No account of the development of the wings and flight muscles in a species where the female is apterous has, however, as far as I know, yet been given.

Young stages of *Lamarckiana* sp. were very kindly given to me by Dr. B. P. Uvarov, F.R.S., for whom Dr. E. Burtt had collected them in Africa. Dr. Burtt was also good enough to send me some adults and various instars of *Saussurea stuhlmanniana*, and adults, and what were probably final instars, of *Tanita dispar*. *Saussurea* is another pamphagine, in which the males are fully winged and the females apterous as in *Lamarckiana* sp., while *Tanita* belongs to the Pyrgomorphinae. In *T. dispar*, according to Burtt (1951), the males, which are fully winged, can fly, but the females, which usually have both fore and hind wings reduced in size, cannot. The size of the wings in the females varies somewhat, and occasionally specimens with fully developed wings, and which are capable of flight, are produced, but none of these were examined. As the material was available, a brief examination of the flight muscles of both species, and of the development of the wings in *Saussurea*, was made in order to compare them with *Lamarckiana* sp.

All material had been fixed in Pampel's fluid, but was transferred to alcohol before use. Examination of the muscles was made by cutting the specimen in half in the median plane and dissecting under a binocular microscope.

Lamarckiana sp.

Number of Instars.

Before the work on *Lamarckiana* sp. could be started, it was necessary to establish the number of instars. Burtt had decided that there were probably six instars, but no measurements had been made. The material consisted of 83 males and 87 females. The measurements taken were the length of hind femur (F), and the length (P) and height (H) of the pronotum : both sides of each specimen were measured and the mean of the two measurements taken. In specimens with a pronotal length of 7 mm. or more, measurements were made with dividers and a millimetre scale: in those with a pronotal length of less than 7 mm., a micrometer eyepiece in a binocular microscope was used. There was often a slight discrepancy between the results obtained by the two methods in the specimens on which both methods were tried, but it was seldom more than 0·3 mm., and the change in method at a pronotal length of 7 mm. does not appear to have made any significant difference to the results. The measurements were arranged in groups with a range of 0·5 mm. and the results plotted:

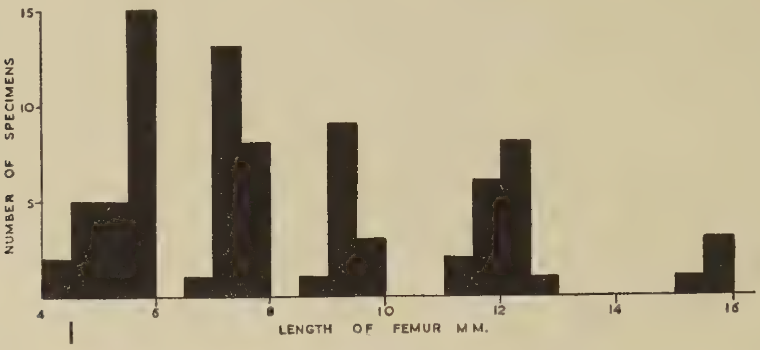

Fig. 1.—Variation in length of femur in male instars of *Lamarckiana* sp. Number of specimens in 0·5 mm. length groups.

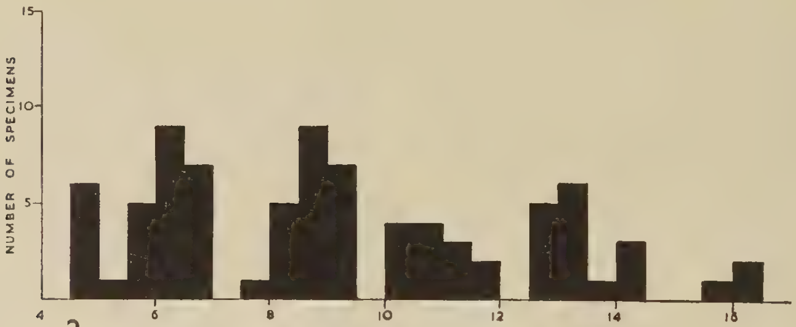

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Fig. 2.—Variation in height of pronotum in male instars of *Lamarckiana* sp. in 0·5 mm. length groups.

those for length of femur and height of pronotum in males and for length of femur in females are shown in figs. 1, 2, 3. A few specimens had become dry, owing to loss of preservative before I received them. This only caused difficulty in the young stages and is considered later.

In the males, using F as a criterion, five groups of individuals were apparent (fig. 1): using P and H as criteria (fig. 2), six groups were seen, each group containing the same individuals (with two exceptions) as when F was used, except that the group with the smaller femur lengths was separated into two groups: the specimens in the lower size group were the only ones to have become dry. On studying the external genitalia of these two groups it appeared that they probably did represent different instars. It seemed very probable then that there were six instars in the development of male *Lamarckiana* sp. and the following work is based on this assumption.

In the females, when F was used as a measure, five clearly demarcated groups were apparent (fig. 3); two individuals in the length of femur range 4·5–4·9 mm. appeared to constitute another possible group, but they were, unfortunately, the only females of approximately this size to become dry. Examination of their external genitalia seemed to show that these were younger than those in the next group. When P and H were used as criteria, the females fell into six groups, the same individuals appearing in corresponding groups whether P, H or F were used, with the exception of one specimen which appeared in a different group when H was used, and three which might have belonged to one of two groups. It will therefore be assumed that there are six instars in the development of the female.

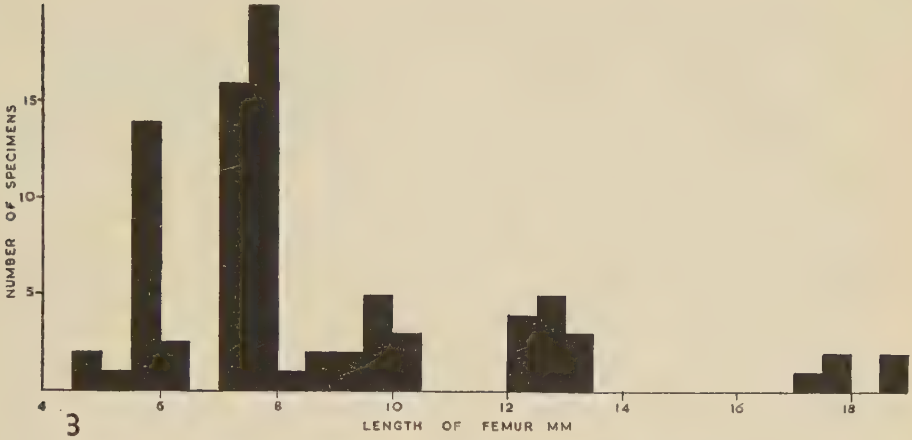


Fig. 3.—Variation in length of femur in female instars of *Lamarckiana* sp. Number of specimens in 0·5 mm. length groups.

Development of the Exoskeleton

There are marked differences in the pterothoracic exoskeleton of the adults of the two sexes of *Lamarckiana* sp. (Thomas, 1952). The female shows greater sclerotisation than the male, the male only has a large postnotum, and there is a difference in the shape of the pronotum.

It is not possible to detect any constant difference in the sclerotisation of the nymphal stages of the two sexes. In the adult male there is a well-developed postnotum which extends downwards to lie posterior to part of the metepimeron and is partly separated from it by a membranous area. In the fifth and sixth male instars the lateral part of the postnotum is present, and the exoskeleton lying below the reduplication of the metatergum may also represent part of it.

In the earlier stages a small region, again partly separated from the metepimeron by a membrane, represents the lateral part of the postnotum.

In the adult female it is difficult to discern any sclerotised postnotum, though the membranous region, which in the male separates it from the metepimeron, is present. In the instars it appears to be present as a small sclerotised region, often separated from the pleuron by a small membrane, which in the sixth instar is relatively large.

Thomas (1952) showed that there is a difference in shape of the pronotum in adult males and females of *Lamarckiana* sp., as shown by the ratio P/H. To find whether this difference was shown by all the instars the mean ratio was found for each instar of each sex. The results for the males are given in Table I, and show a gradual increase in successive instars.

Table I.—*P/H Ratio for Male Instars of* Lamarckiana *sp.*

	Mean P/H.	Maximum P/H.	Minimum P/H.
Instar I	0·90	0·93	0·88
,, II	0·96	1·00	0·91
,, III	0·99	1·02	0·95
,, IV	1·08	1·15	0·98
,, V	1·22	1·36	1·11
,, VI	1·37	1·38	1·36
Adult*	1·35	1·44	1·28

* From Thomas (1952).

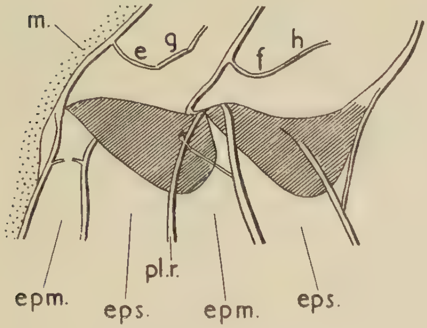
In the females the ratio varied between 0·87 and 1·04, but there appeared to be no correlation between number of instar and P/H ratio. In the adult females the ratio varied between 0·95 and 1·08 in the ten individuals examined.

In the adult female there are well-developed ridges in the region of the junction of pleura and terga of the pterothorax and on the tergum above this (Thomas, 1952). The ridges *e*, *g* in the mesothorax, and *f*, *h* in the metathorax of the adult female seem to be represented in the instars of both sexes and will be designated by these letters (figs. 4, 5). Each ridge starts at or near the antecosta at the front of the segment; at first it runs back parallel with the top of the pleuron and then turns dorsally. In the fifth and sixth male instars, when the wing buds turn up instead of down as in the previous instars, the anterior parts of these ridges form the ventral edge of the tergum.

Development of the Wings.

In the male *Lamarckiana* sp. the wings develop in a typical acridid manner. In the first instar the wing buds are visible as very small ventral projections between the terga and pleura of meso- and metathorax. The fore wing buds in most specimens project very slightly posteriorly but the hind ones show no such tendency. In the second instar both pairs of wing buds become more marked and those of the fore wings show a definite backward projection: both pairs of wing buds are larger in the third instar and the backward projections of the fore wings more marked (fig. 4). By the fourth instar the hind wing buds as well as the fore have posterior projections, although those of the fore wing are larger. Both pairs of wing buds change their direction at the moult preceding the fifth instar, so that in the latter both fore and hind wing buds, which are now of a fair size, are pointing dorsally and posteriorly, the hind lying on top of the fore. This position is kept in the sixth instar, where both pairs of wing buds are larger, but becomes reversed again at the final moult.

Although the adult female of *Lamarckiana* sp. is completely apterous, signs of wing buds are seen during development. In the first instar (only one specimen was available for examination) a pair of small ventral projections between the terga and pleura of the meso- and metathorax are visible : neither has any posterior extension, and they are relatively smaller than in the male. In the second, third (fig. 5), and fourth instars there is practically no ventral increase in size of the wing buds, although they increase antero-posteriorly with the increase in width of the pterothoracic segments. In the fifth instar it is not so easy to recognise any buds, although apparently very shallow folds are still present : these have disappeared completely in the sixth instar.



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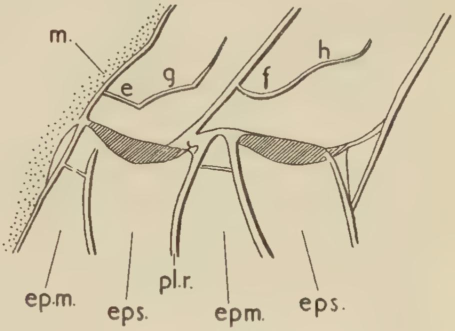

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FIG. 4.—Inner view of part of the pterothoracic exoskeleton of a third instar male of *Lamarckiana* sp. to show wing buds (indicated by shading). *e, f, g, h,* indicate ridges (see text) ; *epm.*, epimeron ; *eps.*, episternum ; *m.*, membrane between pro- and mesothorax ; *pl.r.*, pleural ridge.

FIG. 5.—Inner view of part of the pterothoracic exoskeleton of a third instar female of *Lamarckiana* sp. to show wing buds (indicated by shading). Abbreviations as in Fig. 4.

Development of the Flight Muscles.

The flight muscles of the adults of both sexes have already been described (Thomas, 1952). In the male the chief flight muscles are all well developed and consist of the following, all of which are paired, in each pterothoracic segment :

> Dorsal longitudinal muscle, passing from first to second phragma in the mesothorax, and from second phragma to third phragma, antecosta and postnotum in the metathorax.
>
> Tergo-sternal muscles (of which there are two in the meso- and one in the metathorax), passing from sternum to tergum.

First and second pronator-extensor muscles passing from sternum to first basalare in the mesothorax, and to first and second in the metathorax.

Depressor-extensor muscle from sternum to subalare.

Pleuro-alar muscle running from pleuron to wing.

It has been shown that in the adult female the dorsal longitudinal, the tergo-sternal and the first pronator-extensor muscles are very much reduced and only represented by strands, and that the pleuro-alar muscle is much smaller, or is possibly absent.

Other muscles which, it has been thought, may be associated with flight (see, for example, Misra (1947) on *Schistocerca gregaria*) are the oblique dorsal muscles which are about equally developed in males and females and the tergo-pleural muscles. Many of these are absent in the adult. It seems unlikely that the tergo-pleural muscles in at any rate some Acrididae are associated with flight (Thomas, unpublished work).

Both of these groups of muscles, as well as the muscles known to be associated with flight, have been examined in the second to sixth instars of both sexes of *Lamarckiana* sp. No attempt was made to examine the muscles of the first instar, since these specimens had been dry for a period.

The following account is based on the examination of, usually, three specimens of each instar of each sex.

The dorsal longitudinal muscles in the male are not more than strands in the second and third instars ; in the fourth they seem to attain the development of very thin muscles while in the fifth and sixth instars they are rather larger. If old specimens of the sixth instar were examined it is possible that considerably larger ones would be found. In the female these muscles are never more than strands.

The tergo-sternal muscles of the male are rather more than strands even in the second instar, they are definitely small muscles in the third instar, and become progressively larger until in the sixth instar they are quite well developed. In the female, however, they are never represented by more than strands and in some individuals are difficult to identify.

The first pronator-extensor muscles are present as very thin muscles or thick strands in the second instar : they increase in size throughout the succeeding instars until in the sixth they are relatively large muscles. The same muscles in the female are never represented by more than strands, and in some specimens these, like the tergo-sternals, are difficult to find.

In the male the second pronator-extensors are small muscles in the second instar, gradually increasing in size in succeeding instars, until in the sixth they are well developed. The corresponding muscles of the female are visible as small muscles in the second instar, and increase in the following instars until in the sixth they are well developed.

The depressor-extensor muscles of the males are the largest flight muscles present in each instar : in all instars they are considerably larger in the meta- than in the mesothorax. In the female these muscles are also the largest flight muscles, their absolute size being comparable with those of the corresponding instar of the male.

The dorsal oblique and the tergo-pleural muscles show little difference in the instars of the two sexes and on the whole show a steady increase in absolute size through the various instars, though never attaining a large size.

There are three pairs of dorsal oblique muscles in the meso- and metathorax of each instar. Each arises from the antecosta at the posterior end of meso- and metathorax (except in the later male instars, where they arise from the postnotum or the anterior end of the reduplication of the tergum) and passes forward or obliquely forward to its insertion on the tergum. The third dorsal oblique muscles are absent from the adult. The possible function of the first two pairs has been discussed previously (Thomas, 1952).

There are six pairs of tergo-pleural muscles, one of which is found only in the metathorax, the others being found in both segments. There is also a very thin muscle in the mesothorax, passing from the mesepimeron, rather below and behind the mid-point of the latter, dorsally and slightly posteriorly, to its insertion on the top of the pleuron. Since this and most of the tergo-pleural muscles, as well as the third dorsal oblique, are not generally present in the adults of either sex, it seems unlikely that they can play any part in flight movements and will therefore not be considered in more detail.

No attempt was made to trace the development of the very small dorsal transverse muscle present in the adult male.

COMPARISON OF *SAUSSUREA STUHLMANNIANA* AND *TANITA DISPAR* WITH *LAMARCKIANA* SP.

The nymphs of *Saussurea stuhlmanniana* available for examination were considerably fewer than those of *Lamarckiana* sp.—15 males and 24 females. By making similar measurements to those for *Lamarckiana*, it seemed probable that there were six instars in each sex, although no specimens of the fifth instar males were found. If this number is correct, the first five female instars have very small wing buds, which are absent from the sixth instar. Although only a few specimens were examined, it seems that the development of the flight muscles is similar to that in *Lamarckiana*.

In *Tanita dispar* the only nymphs available probably all belonged to the last instar. The wing buds were well developed in both sexes but those of the female were on the whole smaller, relative to the size of the body, than those of the male. The flight muscles of about five adults and five nymphs of each sex were examined: in the nymphs there seemed no great difference in the development of the dorsal longitudinal, the tergo-sternal and the first pronator-extensor muscles in the two sexes, but in the adult these same muscles were much better developed in males than in females.

DISCUSSION.

Although the wing buds of the female instars of *Lamarckiana* sp. are always small compared with those of the male, the actual decrease in size of these buds takes place after the fourth instar, which is the same time at which inversion of the wing buds occurs in the male: it is possible that the decrease in size at this stage may be connected with an inability to reverse their position. The flight muscles that are much reduced in the adult female, i.e., the dorsal longitudinal, the tergo-sternal and the first pronator-extensor muscles, are never much more than strands in any instar and do not show a relatively greater development in the early instars, correlated with the presence of small wings in these stages.

The presence of small but definite dorsal longitudinal, tergo-sternal and first pronator-extensor muscles, which must presumably be functionless, in the adult females of *Tanita dispar* is of interest compared with their very great reduction in the apterous females of *Lamarckiana* and *Saussurea* and the brachypterous females of the acridine *Chorthippus parallelus*. It leads to the speculation as to whether the better development of the wing muscles in *T. dispar* is due to the brachypterous condition in the female of this species being a more recent development than in *C. parallelus*, and whether these may both illustrate stages in the formation of completely apterous individuals, such as are found in *Lamarckiana* sp.

In the Acrididae so far examined the flightless condition always appears to be characterised by loss or some reduction of the wings and the loss or reduction of flight muscles: the condition found in some other flightless insects, where the wings are well developed, but the flight muscles are reduced, e.g., the beetle *Noterus capricornis* Herbst (Jackson, 1950) and the hemipteran *Nepa cinerea* L. (Poisson, 1921) has not, so far as I know, been recorded for Acrididae.

Poor development or absence of flight muscles in the adult insect can be achieved in various ways:

1. Most of the muscles may never be present as more than strands even in the young stages, e.g., females of *Lamarckiana* sp.
2. The muscles may degenerate during development, e.g., the hemipteran *Nepa cinerea* (Poisson, 1922).
3. The muscles may be functional for some part of the adult life but degenerate later (the degeneration not, however, being correlated with development of the ovaries), e.g., the weevil *Sitona hispidula* (Jackson, 1933).
4. The muscles may degenerate as the eggs develop, as in a mosquito, probably *Aëdes communis* De Geer (Hocking, 1952).

So far only the first method has been shown to occur in acridids, although in *Tanita dispar* there appears to be a relative decrease in the size of muscles between the last instar and the adult.

ACKNOWLEDGMENTS.

I should like to thank Dr. B. P. Uvarov, F.R.S., who suggested the work, for his interest and help, and Dr. Eric Burtt for his trouble in collecting the specimens.

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NOTES ON THE EARLY STAGES OF *RHOPALUS PARUMPUNCTATUS* SCHILL. (HEMIPTERA : COREIDAE).

By H. L. G. Stroyan, M.A., F.R.E.S.

Little appears to have been published about the biology of the early stages of the British Rhopalinae. Butler (1923) described in some detail the ova and young nymphs of *Myrmus miriformis* Fall. and *Chorosoma schillingi* Schml., and gave miscellaneous particulars of later instars of these, of *Therapha hyoscyami* L. and of several species of *Corizus*. He did not, however, give any very positive data on the feeding habits of the early stages, except for some fragmentary observations indicating that young nymphs of *Myrmus* would suck a " fine grass," perhaps *Festuca* or *Deschampsia flexuosa*.

Dicker (1945) records older nymphs of *Rhopalus parumpunctatus* Schill. together with adults as found under *Spergularia rubra* in three localities in Dorset and Hampshire, and refers to another locality where the same species was found attached to *Sagina* sp. in the absence of *Spergularia*. He also suggests that *Erodium* may be another host.

Woodward has recently (1952) described in much detail the reproductive cycle of *Myrmus miriformis* L., giving a very full account of the morphology and water relations of the ova during development. He found that the eggs contain at the outset all the water required for development. He further records the fact that the species is apparently entirely phytophagous and shows a preference for unripe grass seeds.

It may be of interest to put on record some rather incomplete observations made during the summer of 1952 on the ova and first three nymphal stadia of *Rhopalus parumpunctatus* Schill. These observations bear out previous accounts referred to above in a number of particulars, and it is felt that publication is desirable for this reason.

1. *Oviposition.*

A female *Rhopalus parumpunctatus* was taken on a dry sandy roadside between Barton Mills and Icklington, Suffolk, on 21st May. It was flying and alighting on mixed low vegetation consisting of *Lamium*, *Ballota*, *Erodium*, *Rumex acetosella*, *Koeleria cristata*, *Echium vulgare*, *Carex arenaria*, etc. While confined in a tin overnight with some leaves of *Ballota* and a few grass stems this female deposited nine ova singly or in pairs. These were attached to the vegetation by the dorsal surface, the orientation being much as described by Woodward for *Myrmus*. The ova are, however, laid flat on the substratum, and not elevated on a short stalk arising from the dorsal surface as in *Myrmus* ; though one microphotograph (Plate 1) shows traces of an oval flattened area dorsally which perhaps corresponds to the stalk area of *Myrmus*.

2. *Description of Ova.*

When first laid the egg is elongate oval, rather smoothly rounded, pale straw-coloured to ochreous yellow, shining and with a pearly iridescence. The whole surface of the chorion is covered with a rather large polygonal reticulation, which is extremely faint and hard to see except on strongly illuminated areas. The free (ventral) surface is largely occupied by an elongate 8-shaped or dumb-bell-shaped opercular area, demarcated by a slightly raised line, marking the future line of dehiscence of the chorion. This line is conspicuous round the anterior end of the operculum, but becomes much less apparent posteriorly. At the narrowest point of the operculum the line of dehiscence is rather more raised and thickened into a brown-pigmented lip on either side, and between these two lips lies a band of apparent thickening of the chorion, which looks as if it is holding together the lips. Another way of describing this is to compare the appearance of the non-opercular surface of the egg with a wrapping applied round the dorsal side of the egg, drawn together at the middle of the ventral surface and secured by a band of adhesive. The micropylar area of the egg is provided with two small subconical or top-shaped processes, one situated within the anterior half of the operculum and the other on the dorsal surface in a corresponding position. The opercular area is smooth, not granulated as described for *Myrmus*.

3. *Development of Ova.*

The first noticeable change is a darkening of the general colour of the egg to an orange-yellow, after which spots of irregular shape and a bright red colour appear at various points within the egg contents. The red colour progressively increases, until after 18 days (i.e., just before hatching) the contents appear rather uniformly dark red at the anterior pole, except where the legs of the contained nymph can be made out, being of a rather dull ochreous hue. The posterior end at this time is rather duller in colour, of an olive brownish tint. The chorion retains its rather yellowish nacreous lustre, and as the nymph develops the reticulation of the chorion becomes much more apparent when the egg is viewed under the binocular by reflected light. From 17 days (and perhaps earlier) it is possible to see the stiff black hairs of the developing nymph through the chorion.

During development the sides of the egg become pulled in and concave, presumably due to a closed water economy combined with differential elasticity between the sides and the operculum. The final shape of the egg is rather like a purse with a wide, curved and convex bottom (the dorsal surface), concave sides, and the mouth and clasp represented by the elongate operculum and its median thickened band respectively.

Hatching of the ova took place on the night of 8th–9th June, thus giving a duration of the egg stage of about 18 days. Eclosion is brought about by the bursting of the anterior half of the operculum along its line of dehiscence. The inner embryonal envelope remains protruding from the empty chorion, which is ochreous yellow. It is interesting to note that in contrast to the ova of *Chorosoma* and *Myrmus*, discussed by Woodward, the ova of *R. parumpunctatus* are apparently laid in the spring and develop directly without diapause. Dicker (1945) has observed copulation in autumn, but observed no males of the species earlier in the year than July. He concludes from this that probably the female alone overwinters.

No experimental evidence is available in support of the supposition that the water economy of *R. parumpunctatus* ova is a closed system like that of *Myrmus*;

but observations pointing in this direction are the strongly marked change of shape by the sinking in of the sides of the egg during development, and the rapid and normal development of the eggs under artificial conditions much drier than those which would normally prevail in the field. At one stage a piece of moistened filter-paper was introduced into the Petri dish containing the eggs, but no reversal of the progressive sinking in of the sides of the eggs was observed following this. If it is in fact true that these eggs have a closed water economy it would seem that this feature is unconnected with the presence or absence of diapause in the egg stage.

4. *Nymph, First Instar.*

The young nymphs show the disproportionately large head, thorax and antennae recorded for young nymphs of *Myrmus*. The whole body and limbs are clothed with rather long, stiff, apically truncate-clavate black hairs. When first hatched the tiny nymph has the head, thorax, antennae and femora bright red, the apical quarter of joints I–III of the antennae whitish, the femora basally and apically also whitish and the tibiae whitish with red spots. The abdomen is ochreous yellow. Within a very few hours all the red parts of the body have darkened to a deep pitchy colour tinged with red in places. The abdomen has a darkened sclerotic ring round the 8th segment, within which is telescoped the 9th. The orifices of the scent-glands are to be seen on the mid-dorsum of the 3rd and 4th abdominal segments.

A macerated specimen examined in chloral-phenol showed the following morphological details :

Head much produced between the antennal bases, sclerotic, with the frontal and occipital regions delimited by a somewhat T-shaped suture, the arms of which are rather sinuate and reach the dorsal border of the compound eyes at about half the antero-posterior length of the latter ; the shaft of the T is produced forward a little on to the frontal region before disappearing. *Hairs* on the head are situated as follows : clypeolabral area (delimited by a pair of grooves enclosing an anteromedial raised area) 10 hairs. Frontal area proper, 10 hairs on discal part, in a series of transverse pairs or rows with arrangement 2.2.4.2 ; also the first 4–5 of a series of 6–7 hairs lying along the dorsal margin of the compound eye are situated on the frontal area, the remainder on the occipital area. Occipital area, 2 hairs each side on the vertex in addition to the above-mentioned hairs along the margin of the eye. *Antennae* 4-segmented, apical segment rather thicker than the remainder, and with the stiff black hairs intermingled with shorter finer ones. *Compound eyes* convex, nearly equal in antero-posterior diameter to the length of antennal joint I. *Rostrum* reaching about to third abdominal sternite, clothed with finer hairs than remainder of body ; apical joint nearly as long as ant. IV. *Pro-* and *mesonotum* each with a medially divided sclerotic bar ; *metanotum* with only a small sclerotic spot at each side. *Pleura* crescentic, well sclerotised, pleural suture distinct, trochantins of coxal articulations also conspicuous. *Pro-* and *metanotum* each with a double, *mesonotum* with only a single transverse row of body hairs, each row consisting of 2–3 hairs on each side of the mid-line. Each segment of the thorax bears 3–5 very small fine hairs on the membrane between the tergites and pleurites ; and each episternum and epimeron of the latter may also have one or two very small hairs at the coxal margin. *Sterna* membranous. *Abdominal* dorsum membranous except for tergites 8 and 9, which are sclerotised ; each tergite with a single transverse row of stiff body hairs, the arrangement of which is : (1) a spinal series of pairs, present throughout ; (2) spinopleural pairs on each side, present only to segment 5 ; (3) marginal pairs on each side, present to segment 7, and a single marginal each side on 8.

Thus the tergal chaetotaxy of the segments is (1–5) 10 : (6–7) 6 : (8) 4 : (9) 2. The ventral chaetotaxy is rather similar, but the hairs of the first two sternites are rather thinner and smaller than the dorsal hairs, and those of 3 and 4 are transitional to the stiffer dorsal type. *Trichobothria* are distributed on the ventral surface as follows : one either side of the mid-line on seg. 2 ; two either side of the mid-line on seg. 3 ; a closely approximated pair laterally on either side on segs. 4–5 ; and a single one laterally on either side on seg. 6. *Spiracles* : both thoracic and 7 abdominal pairs are well-marked. The orifices of the scent-glands open on the mid-line of the 3rd and 4th abdominal tergites. *Legs* fairly stout ; hind femora and tibiae subequal in length, about equal to ant. IV ; tarsal joint 1 about half length of joint 2, the tarsal joints ventrally with numerous fine acute hairs.

When the bug is from 2–3 days old a small orange spot becomes visible on the back of the abdomen just in front of the orifices of the scent-glands.

Measurements in stadium 1 : Body 1·3 mm. Rostrum 0·7 mm. Proportions of antennal segments about 7 : 12 : 14 : 19, total length of antenna 0·8 mm. Stiff body hairs up to about 0·1 mm. long.

5. *Nymph, Second Instar* (from one specimen).

Very similar to first instar in coloration ; only the ring-spotting of the tibiae is more pronounced. The dorsal abdominal hairs now arise from small round dusky sclerotic plaques, while on the margins of the abdominal tergites from segments 1–6 inclusive there is a series of blunt conical projections which project laterad ; these increase progressively in size posteriorly, and there is even a trace of a small similar projection on the lateral margin of the metanotum. On the anterior surface of each of these projections from segs. 2–6 inclusive there is a more or less triangular blackish spot. Each projection bears the marginal dorsal hair at its apex, and a second similar hair lateroventral to its base. Trichobothria are now present ventrally as before, except that there are three on either side of the mid-line in a single transverse row on seg. 3, and two at each lateral margin of seg. 6, instead of two and one respectively on either side of the same segments in stadium 1.

Measurements of specimen : Body 2·11 mm., greatest width of abdomen 0·80, head between eyes 0·40, antennal segments 19 : 29 : 29 : 45, total length 1·22, apical joint of rostrum 0·35, 2nd joint of hind tarsus 0·29 mm.

6. *Nymph, Third Instar* (from one specimen).

Considerably larger and relatively broader than 2nd instar, and abdomen more dorsally flattened. The yellow colour of the abdomen is more opaque, and is sprinkled with dots of red, particularly intersegmentally and round the sclerotic hair plaques. The lateral margins are somewhat concave and upturned, forming a rudimentary connexivum. The marginal projections owing to this are now directed upwards rather than laterad ; they are now blackish anteriorly and ivory-coloured posteriorly. The sutural line on the vertex of the head is rather Y-shaped in this instar, and is produced backwards on to the mid-line of the pro- and mesonotum as a cream-coloured line ; it is itself rather widely margined with the same colour. There is also a very obtuse median cream-coloured protuberance on the metanotum. The number of dorsal hairs on the abdomen is increased by the development of a small number of smaller, finer hairs interspersed between the regular series. These do not stand on sclerotic plaques. Each lateral prominence also has now 2–4 small fine hairs around its base in addition to those present in the previous instar. Antennal segments II and III are conspicuously ring-spotted like the tibiae. Trichobothria are now arranged : 2 St, 1 + 1, mid-ventral ; 3 St, 3 + 3, mid-ventral ; 4 St, 3 + 3, lateral ; 5 St, 3 + 3, lateral ; 6 St, 2 + 2, lateral. The ventral surface of the abdomen is scattered with small red dots chiefly around the bases of the hairs, while the sternal cuticle of the thorax is rather solidly red-pigmented.

Measurements of specimen: Body 2·37 mm., greatest width of abdomen 1·40, head between eyes 0·51, antennal segments 24 : 43 : 42 : 54, total length 1·63, apical joint of rostrum 0·35, 2nd joint of hind tarsus 0·29 mm.

No material was obtained of any instar later than the third.

7. *Biological Observations.*

(a) *Nymphal behaviour, first instar.*—The small bugs were active under the conditions prevailing in the Petri dish in which they were confined, walking about rapidly over the vegetation and the glass sides of the dish. The abdomen in life was held cocked up at a steep angle. When approached by a needle-point, brush or other instrument the reaction was a quick evasive movement, sometimes so violent that the young nymph fell over backwards with its long legs in the air. It would then rapidly seize the point of the needle or brush or any other object presented to its feet, and its agility and ability to remain poised on such a small foothold would have done credit to a chamois!

(b) *Feeding.*—As the writer was unaware at the time of hatching of the ova of the note by Dicker on *Spergularia* as a host, the newly emerged nymphs were placed immediately in a Petri dish with a selection of fresh plant foliage as nearly as possible representative of the habitat in which the parent bug was captured. This mixture was made up of:

Echium vulgare L., *Erodium cicutarium* L'Hérit., *Geranium pusillum* L., *Potentilla reptans* L., *Vicia cracca* L., *Ballota nigra* L., *Carex arenaria* L. and *Koeleria cristata* Pers.

Occasional probes were made by the nymphs while under observation, but no prolonged feeding was seen. However, next morning some nymphs were seen with the abdomen distended, having apparently taken some nourishment during the night. All were then (10th June) wandering about over the foliage, and no congregation on any one plant could be detected, apart from a group of three, which soon dispersed, on one shoot of *Erodium*. When in movement over the vegetation the antennae were carried porrected at an angle of about 80–90°, and were used for alternating palpations of the substratum when the bug was engaged in probing.

On 11th June the diet was supplemented by the introduction of some inflorescences of *Dactylis glomerata* L., and it was on one of these that the first instance of really purposeful feeding behaviour was noted. The time was about 3 p.m. on 12th June, and at this time, when conditions in the Petri dish appeared to be somewhat warm and humid, a certain amount of probing was seen among the nymphs, one of which was probing the glass side of the dish and others the vegetation. One nymph on *Dactylis* was seen in what appeared to be a typical feeding position, the antennae being drawn back over the thorax instead of porrected, and the head being slightly raised and lowered alternately in a rhythmic and characteristic way. On closer inspection the stylet bundle could be seen clearly inserted into the tissue of the inflorescence, while the labium was retracted under the body of the bug. Whether this was the normal feeding position of the rostrum could not be made certain, as it may merely have been retracted prior to withdrawal of the stylets, which did in fact occur about half a minute later, after which the stylet bundle was "combed out" by the front legs and returned to the labial groove. The nymph then moved away a little and began probing again on the same inflorescence ; it was later joined by a second which also began to probe. The distended abdomen of the first nymph at this stage gave good reason to believe that some appreciable amount of nourishment had been taken from the grass.

At 3.30 p.m. the same two nymphs were again seen to be motionless and apparently inserted, and at 4.40 p.m. two nymphs, whether the same two was not certain, were again feeding on the *Dactylis*, one being engaged in sucking an anther. In all these four instances the rostrum was held apposed to the plant surface and not retracted. However, a little later several instances of feeding with retracted labium were noted on sepals of *Geranium*, and feeding was seen to continue for an appreciable time with the labium held in this posture.

Up to this time no animal food had been offered to the bugs, but in view of the known carnivorous tastes of many Heteroptera it seemed desirable to test the possibility of such habits in *Rhopalus*. Accordingly, on the evening of 12th June fresh food was introduced into the Petri dish, consisting of inflorescences of *Dactylis*, shoots with developing capsules of *Erodium* and a small shoot of garden rose bearing a fair number of immature forms of the aphid *Macrosiphum rosae* (L.). Next morning all the bugs which could be detected were sitting and/or feeding on the grass heads, and the aphids had all remained apparently unmolested. They subsequently survived in good health until the rose shoot became too desiccated to support them.

From this point feeding of the bugs was continued on a mixture of *Dactylis*, *Geranium* and *Erodium* only. About 18th June it was noticed that *Dactylis* no longer proved attractive, and from this time only *Erodium* was given. On this host the nymphs showed a marked preference for the sepals of the fruiting flowers. Growth was slow, and mortalities occurred at intervals, suggesting that a pure diet of *Erodium* was not very satisfactory nutritionally. Only two nymphs successfully moulted into stadium 2, and of these one survived to stadium 3, finally dying on 11th July after an unavoidable lapse of two days without fresh food.

The foregoing data, while inconclusive, are interesting as showing that the taste for unripe seeds of grasses shown by *Myrmus miriformis* nymphs also occurs in *Rhopalus parumpunctatus*, and that the ability to use *Erodium* as a host, suspected by Dicker and inherently probable from the general popularity of *Erodium* among Heteroptera, is a fact. It was unfortunate that ignorance of the association with Caryophyllaceae found by Dicker prevented experiments with members of that order. It seems likely, however, that the range of host-plants offered could not provide the full nutritional requirements of the bugs, and it seems not unreasonable to suppose that the addition of *Spergularia* to the diet might have made the difference between success and failure in rearing the adult bugs.

(c) *Duration of instars.*—The two nymphs surviving to stadium 2 moulted on the night of 25th June. The last survivor moulted to stadium 3 on the night of 1st–2nd July. The durations of the first two stadia were therefore 16 and 6 days respectively. The last nymph survived for 5 days in the 3rd instar. It is not possible to gauge how nearly these durations approximate to the normal durations in the field, owing to ignorance of the relative inadequacy of the diet and absence of any recorded temperature and humidity data, which must have varied very considerably.

SUMMARY.

An account is given of an attempt to rear *Rhopalus parumpunctatus* Schill. from the egg. Descriptions are given of the ova and first three nymphal instars. Feeding was recorded with some degree of success on *Dactylis glomerata*, *Erodium cicutarium* and *Geranium pusillum*, but these do not appear to form an adequate diet for the completion of growth. *Spergularia rubra*, a previously recorded host, was not given. No evidence was obtained of any carnivorous tastes in the nymphs, aphids remaining unmolested when confined in a Petri dish with them. The ova of *R. parumpunctatus* are apparently laid in the spring and develop directly without diapause.

ACKNOWLEDGMENT.

I am grateful to Dr. G. H. L. Dicker for providing me with the reference to his notes on *R. parumpunctatus* in the *Entomologist's Monthly Magazine.*

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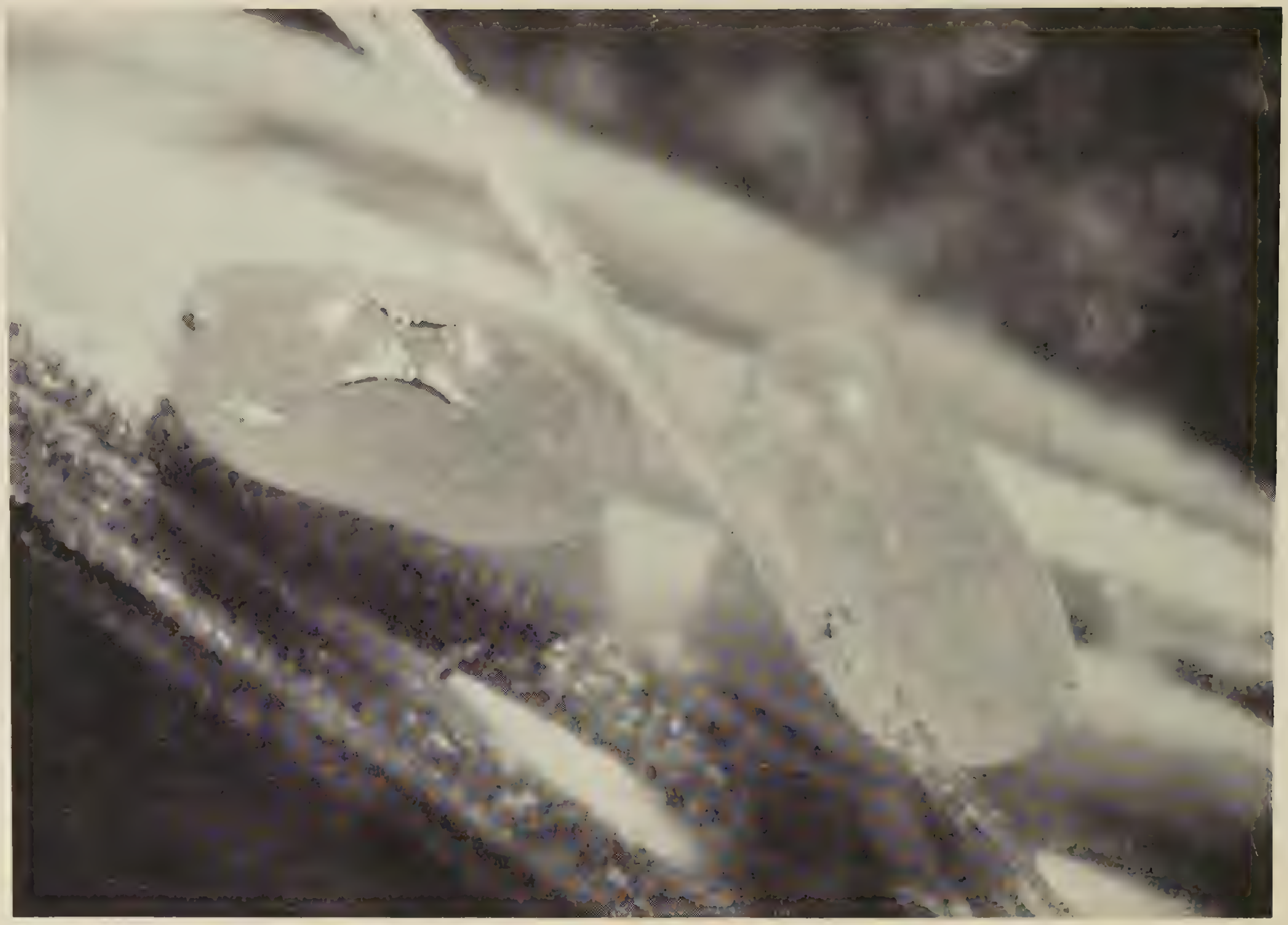

Ova of *Rhopalus parumpunctatus* Schill. × about 80.

DONNÉES SUR LA LEUCOPOIÈSE CHEZ *MUSCA DOMESTICA* L.

Par Mlle. LUCIE ARVY.

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LES données sur la leucopoïèse des Muscides sont très restreintes. Stark et Marshall (1930) décrivent, chez *Drosophila melanogaster* Meigen, sous le nom d'organes sanguiformateurs, deux glandes péricardiales, situées de part et d'autre de la portion antérieure de l'aorte, un peu en avant de l'anneau de Weismann. Rooseboom (1937) estime que, chez *Calliphora erythrocephala* Meigen, "le besoin de globules est satisfait par la mitose des cellules dans le sang circulant" (p. 87). Poulson (1950), enfin, pense que, chez *Drosophila melanogaster* Meigen, quelques leucocytes, dérivent des cellules vitellines et la plupart de la portion médio-ventrale du mésoderme (p. 181).

En fait, l'examen de coupes sériées de *Musca domestica* L. issues d'une même ponte, prélevées à intervalles variés après l'éclosion (3, 6, 21, 30, 45, 60, 72, 120 et 144 heures, pupes jeunes et âgées, imago ♂ et ♀), permet de découvrir un organe leucopoïétique et de suivre son évolution.

L'organe leucopoïétique de *Musca domestica* L. est accolé à la partie toute postérieure de l'hypoderme dorsal et latéral ; il occupe l'angle dièdre formé par les parois dorsale et postérieure du corps, il déborde le long des parois dorso-latérales. Sur les coupes frontales (Fig. 1) il apparaît sous forme de deux amas, situés de part et d'autre des stigmates post-abdominaux, dont ils peuvent être séparés par des muscles ou des adipocytes ou les glandes para-stigmatiques ; ils s'unissent au-dessous des deux gros troncs trachéens et s'étendent le long des faces latérales en formant un U ouvert en avant.

Chez la larve de trois heures, il existe deux petits amas, d'environ 24 leucocytes, du type leucoblaste : cellules pourvues d'un gros noyau clair, nucléolé, et d'une petite couronne de cytoplasme très basophile et pyroninophile ; ils sont ronds ou faiblement ovalaires et mesurent, en moyenne, 7μ de diamètre ; l'organe entier n'excède pas 60 μ de long et 27 μ de large.

Chez la larve de six heures, l'organe atteint 100 μ suivant sa plus grande dimension et 55 μ d'épaisseur.

Chez la larve de 21 *heures*, la partie de l'organe qui occupe de dièdre formé par les faces dorsale et postérieure a la largeur de l'extrémité postérieure de la larve, soit environ 170 μ ; il mesure 100 μ dans le sens antéro-postérieur ; la languette dorso-latérale atteint 390 μ de long et environ 80 μ de large. Dès ce stade, on peut noter une certaine disparité dans la taille des leucocytes : à côté des leucoblastes, il existe des leucocytes qui ont jusqu'à 13 μ de diamètre.

Chez la larve de 30 *heures*, la partie postéro-dorsale de l'organe mesure 580 μ dans le sens transversal et 150 μ dans le sens antéro-postérieur ; la partie dorso-latérale atteint 1120 μ de long et 135 μ d'épaisseur ; suivant les coupes, le bord antérieur, courbé en avant et en dedans, est libre dans la cavité générale ou accolé aux adipocytes ou à des faisceaux musculaires ; à ce stade, les trachéoles qui abordent l'organe, qui sont toujours très nombreuses, sont grosses et particulièrement visibles ; il existe, en outre, de grandes cellules trachéennes (28 μ

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× 22 μ) qui tranchent sur les leucocytes, par leur taille et par la chromophobie de leur cytoplasme.

Chez la larve de 45 *heures,* la partie de l'organe adjacente à la paroi dorso-latérale remonte jusqu'à 1200 μ de l'extrémité postérieure.

Chez la larve de 3, 5 *et* 6 *jours,* l'organe est à peine plus grand ; il est constitué par des leucocytes de toutes tailles, depuis le leucoblaste de 6 μ de diamètre, jusqu'au leucocyte à cytoplasme faiblement basophile, de 16 μ de diamètre.

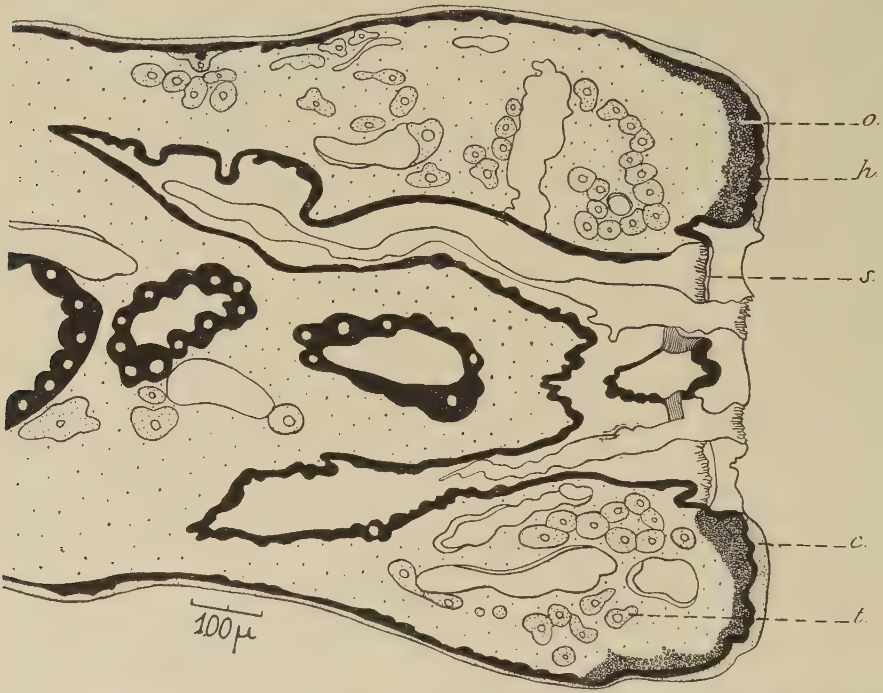

Fig. 1.—Représentation demi-schématique de l'organe leucopoiétique chez une larve de *Musca domestica* L., âgée de 21 heures. (Dessin obtenu par superposition de 5 coupes frontales sériées.) *o* = organe leucopoiétique, *h* = hypoderme, *s* = stigmate post-abdominal, *c* = chitine, *t* = tissu adipeux.

Chez la pupe de quelques heures, encore blanche, l'organe leucopoiétique est entièrement dissocié ; les leucocytes libérés s'accolent aux muscles, exactement comme l'a décrit et figuré Pérez (1910).

Chez la pupe de moins de 24 *heures,* il ne reste plus trace de cet organe leucopoiétique et l'imago en est dépourvu.

L'examen à frais de larves de *Musca domestica* L., à divers stades, n'a pas permis de voir de leucocytes dans le sang circulant, comme l'avait décrit Viallanes (1882), chez *Ctenophora* (*Tipulidae*) et chez *Musca* (*Calliphora*) *vomitoria* ; la ponction de l'aorte, avec une fine pipette de verre n'a permis de recueillir que du plasma tenant en suspension de nombreux globules lipidiques de toutes tailles ; enfin, l'examen de coupes sériées de larves de *Musca domestica* L., aussi bien que celle de l'imago, n'a pas montré de leucocytes dans le sang circulant. Par contre, la pupe très jeune, encore blanche, a de très nombreux leucocytes, tant à la ponction que sur coupes histologiques ; la pupe jeune montre des leucocytes en cours de phagocytose et la pupe âgée a son milieu intérieur surchargé de leucocytes remplis de particules phagocytées.

Chez *Musca domestica* L., au moins, les leucocytes ne seraient donc pas des agents de transformation des " peptones de la digestion," comme le voulait Cuénot (1891), mais des phagocytes, dont le rôle essentiel serait de résorber les tissus larvaires.

S'il en est bien ainsi, un organe leucopoiétique doit exister chez tous les Diptères en particulier—même chez le Chironome, Diptère nématocère réputé dépourvu d'éléments sanguins figurés, depuis Cuénot (*loc. cit.*, p. 387 et p. 393)—et chez les Ptérygotes en général. Nous nous proposons de poursuivre nos recherches dans ce sens.

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Book Notices.

The Anatomy of the Migratory Locust. By F. O. Albrecht. 4to. London (Athlone Press), 1953. Pp. xvi + 118, text illus. Price 30*s.*

In this work the author, who is a member of the staff of the Anti-Locust Research Centre, presents a single comprehensive account of the external and internal anatomy of the migratory locust, Part 1 dealing with the external anatomy and Part 2 the internal.

As the locust is of special value as an insect type for teaching purposes the book is also intended to serve in the teaching of general entomology, and the two appendices which follow the main work include instructions for dissecting the locust, and for the demonstration of its structure. The book is very fully illustrated and there is a bibliography of over thirty references.

The Social Insects. By O. W. Richards. 8vo. London (Macdonald), 1953. Pp. xiii + 219, pls., text illus. Price 15*s.*

This book comes at a time when the study of the behaviour of social insects is claiming renewed attention at home and abroad and it will be welcomed by scientists and laymen alike for it brings together in a readable and authoritative form the results of all the most recent researches on these most interesting and perplexing of insects. The development of the social habit is traced from the completely solitary insect through the Embiids and earwigs which show a very rudimentary awakening of mother-care (but omitting mention of the Australian *Pseudoperga* and the quite unrelated S. American *Pachylota* sawflies in which the mother stands guard for a while over her eggs and larvae, especially interesting because within the Order Hymenoptera which, with the exception of the termites, claims all the known instances of the social habit), through certain beetle families in which the parents actually rear their offspring to the adult stage to the true social condition found only among the ants, bees, wasps and termites in which a degree of co-operation is achieved whereby the egg-laying female (the queen) is attended and assisted by other, but normally sterile, females (the workers). Of the 20,200 species of insects in the British fauna a mere 37 ants, about 44 bees and 7 wasps have reached the top of the social ladder and that members of the Hymenoptera should have been able to do so is ascribed to a special form of sex-determination by which the (once only) fertilized female can over a long period lay fertile as well as infertile eggs, producing females and males respectively. On the other hand, in the termites, which have developed an equally advanced social habit, the queen requires frequent fertilization with the consequent necessity of a more or less permanent male (the king) and in addition there are sterile castes of both males and females. The author stresses that notwithstanding the apparent analogies between termites and ants, the differences are profound and more important than the resemblances. The chapters dealing with the *Polistes* and *Polybia* wasps are particularly valuable, being based largely upon hitherto unpublished data and the claim that certain common British species of the bee genus *Halictus* must be looked upon as social insects will cause considerable surprise to those unaware of Stöckhert's work in Germany 30 years ago. Theories of caste production are treated in considerable detail, especial attention being paid to the (non-British) stingless bees in which the larval food is sealed into the cell at the time of oviposition, thus very largely excluding any possibility of differential feeding influencing the resulting caste. Swarming is dealt with in less detail than the average bee-keeper might expect but it is with the principle of this method of increase and not with the artificial control of it that the author is concerned; swarming is shown to occur not only in bees but also in certain wasps (the process of colony foundation by budding in certain ants and termites is to some extent analogous) and it is interesting to learn that in the honey bee alone does the old queen, and not a new young one, depart with the swarm; the point is made that the process of swarming depends in the first place upon a climate which allows continuous breeding or upon a worker caste capable of hibernating like the female and the benefit to a species of this method of increase, involving as it does great sacrifice of direct multiplication, is ascribed to the ever present body of protecting workers. In a chapter devoted to social parasites the author expounds theories to explain the evolution of the cuckoo bees and wasps which have lost the ability to produce a worker caste and the parasitic ants which for a variety of reasons have become unable to exist in any other way. Students of insect behaviour will find much to interest them throughout this book and the reader who is unfamiliar with von Frisch's interpretation of the dances of honey bees, Tinbergen's experiments on direction finding in the solitary wasp *Philanthus*, Santschi's and Carthy's studies of ant behaviour will find the essence of these and other extensive researches clearly explained. The fifty-one photographs which illustrate this book are absolutely first rate, but one cannot say the same of the bibliography which, perhaps as an economy of space, is reduced to a mere handful of titles for further reading.

I. H. H. Yarrow.

A NOTE ON THE ANATOMY AND MORPHOLOGY OF THE EXTERNAL GENITALIA OF *CARPOPHILUS OBSOLETUS* ER. (COLEOPTERA : NITIDULIDAE).

By Ronald M. Dobson, F.R.E.S.

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It has been noted that the male genitalia of some of the species of *Carpophilus* provide characters of taxonomic importance (Dobson, 1952, 1954). It seems probable that if the genus were to be revised much use would be made of genital characters and it is thought that a brief description of the external genitalia of both sexes, and an attempt to standardise the nomenclature of the parts, would be of some value. The female genitalia do not so readily provide usable characters, and in related species may be very similar. It is probable that they would be of use in roughly assessing the position of doubtful species within the genus.

Male.

Eight tergites and five sternites are externally visible in the abdomen (fig. 1). The first sternite is equivalent to the first three tergites behind which the dorsal and ventral plates correspond as far as segment seven. The eighth tergite is a cup-shaped structure, postero-ventral in position and is not normally visible from the dorsal aspect. The last visible sternite (seventh if the first is regarded as consisting of sternites one to three) is deeply emarginated apically to receive the eighth tergite (supplementary segment of many authors), and between the two is a narrow orifice which gives access to the ano-genital chamber within. The eighth tergite is capable of articulation so as to facilitate extrusion of the genitalia through the orifice. Rakshpal (1947*a*), writing of an unspecified species of *Carpophilus*, states that this cup-shaped tergite is the ninth segment, and consists of both sternal and tergal elements. No evidence is produced to support this view and it seems questionable, as in *C. obsoletus* Er. and all the other forms examined, the anal opening is ventral to the structure, being situated on the membrane between it and the genitalia. (Berlese considers that in Coleoptera the first true segment of the abdomen has been lost and if this be the case, the cup-shaped tergite must morphologically be attributed to the ninth segment. Anatomically it is the eighth and is treated here as such.)

The external genitalia are of the generalised trilobe type, and the nomenclature adopted is that of Sharp and Muir (1912). The following structure is apparent (fig. 3).

The intromittent organ, " Median Lobe" is a hollow membranous tube, which in the resting condition lies inverted within itself, and is usually folded twice longitudinally within the body cavity. During copulation, the median lobe can be everted and may then be observed to bear externally a complex and often characteristic armature of denticles. Its apex is pierced by the

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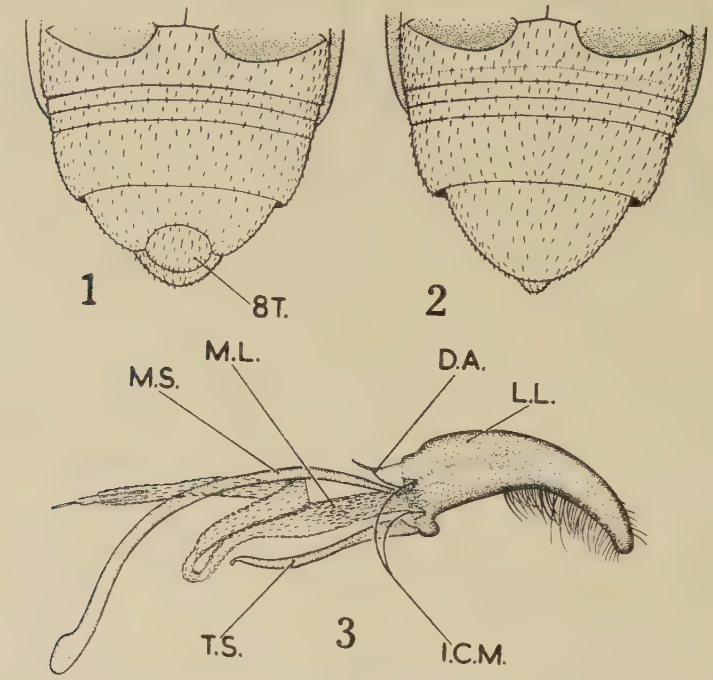
* Now at Rothamsted Experimental Station, Harpenden, Herts.

" Ductus Ejaculatorius " which is prolonged externally into a long " Flagellum " bearing at its tip the functional genital orifice. At its base the median lobe bears a long dorsal apodeme articulated at its posterior end, with its free end projecting forwards into the body cavity. This is the " Median Strut." Basally the median lobe is joined by a membrane, the " First Connecting Membrane," to a sclerotised ring which bears the following structures :

(*a*) Distally a pair of " Lateral Lobes " or " Parameres " which are heavily sclerotised and bear numerous setae.



Figs. 1–3.—*Carpophilus obsoletus.* (1) Abdomen of male (ventral aspect). 8T, tergite of segment 8. (2) Abdomen of female (ventral aspect). (3) Male genitalia (lateral aspect, in resting condition). M.S., median strut ; M.L., median lobe, containing flagellum I.C.M., first connecting membrane ; L.L., lateral lobe ; T.S., tegminal strut ; D.A., dorsal apodeme.

(*b*) Proximally a ventral Y-shaped apodeme, the paired arms of which articulate with the bases of the parameres, the free arm being directed anteriorly. This is the " Tegminal Strut."

(*c*) Proximally and dorsally a small plate-like dorsal apodeme.

The complex of ring, parameres and dorsal apodeme surrounding the median lobe is the " Tegmen " of Sharp and Muir. The various components and the Y-shaped apodeme are regarded as attributes of it. The combination of tegmen and median lobe is the " Aedeagus " of Sharp and Muir.

Connecting the aedeagus to the body wall, and thus forming the genital area of the wall of the ano-genital chamber, is the " Second Connecting Membrane."

The relation of the genitalia to the abdomen is shown in the semi-diagrammatic longitudinal section (fig. 4).

Ventral to the aedeagus and connected to it by the second connecting membrane is a structure of unsettled affinities (figs. 4 and 5). It consists posteriorly of an explanate plate grooved distally to act as a guide for the lateral lobes, and anteriorly of an elongate strut. It is considered by Parsons (1943) to be the 8th sternite and strut, and by Rakshpal (1947*a*), who has studied its mode of origin, to be the "Spiculum Gastrale." According to the latter author it is developed from the ventral part of the median lobe by a horizontal longitudinal splitting. A contribution to the morphology of the spiculum gastrale is outside the scope of this note, but it would seem that if the structure is to be defined morphologically, then the definition given by Sharp and Muir (1912) should be acknowledged. It is stated by these authors to be "A sclerite attached by one end to the second connecting membrane."

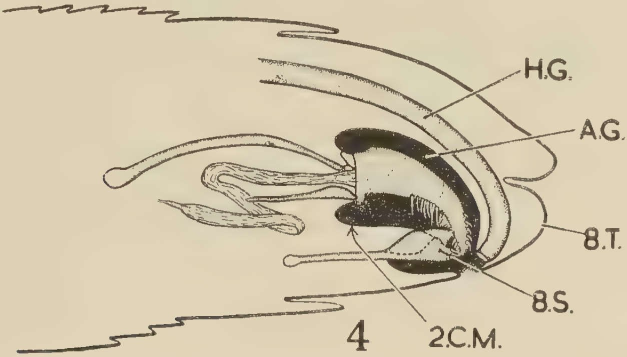


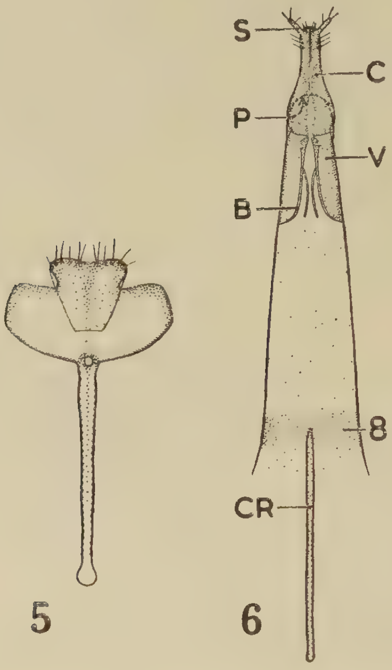
Fig. 4.—*Carpophilus obsoletus.* Longitudinal section of abdomen of male (semi-diagrammatic, to show relations of genitalia). H.G., hind gut; A.G., ano-genital chamber; 8T, tergite of segment eight; 8S, sternite of segment eight; 2 C.M., second connecting membrane.

Hopkins (1911) regards the spiculum as being a modified 9th sternite, but this view is now superseded by those of Singh-Pruthi (1924*a*, *Tenebrio molitor*), Metcalfe (1932, *Sitodrepa panicea*, *Gastroidea polygoni* and *Anthonomus pomorum*) and Muir (1918, *Rhabdocnemis obscura* and *Acantholophus*), who all agree (Singh-Pruthi and Metcalfe having observed the development) that it is formed as an invagination independent of and posterior to the 9th sternite. They disagree only in deciding the exact position of the invagination (Singh-Pruthi—body wall, Metcalfe and Muir—wall of genital pocket, i.e., 2nd connecting membrane of Sharp and Muir).

In *Coccinella reparda*, Muir finds that a structure resembling a spiculum arises as an invagination from the base of the 9th sternite, and in *Ithycerus* he observes that a spiculum co-exists with a similar structure arising from the basal edge of the 8th sternite.

It would seem, therefore, that the term "Spiculum Gastrale" should be reserved for the structure arising posterior to the 9th sternite, and that in the event of similar structures of different origin co-existing with, or functionally replacing the true spiculum, the term " False Spiculum " suggested by Muir should be applied.

In *Carpophilus*, the true affinity of the structure regarded by Rakshpal as being the spiculum seems questionable. I have not been able to study its development, but in the adult it appears to be double in structure in some species and single in others, the posterior explanate portion frequently being articulated to the anterior strut-like portion and with the membrane from the apex of the last external sternite (7th) joining it at the point of articulation. The posterior portion is joined dorsally to the second connecting membrane, so that its ventral surface is in fact, external, while the anterior strut is internal. Parsons (1943) believes the structure to be the modified 8th sternite, and on such evidence as can be obtained from dissection I would agree with him, and regard it as the 8th sternite and its strut, the latter presumably being developed from its anterior edge as in the case of *Ithycerus* cited above. Support for this view may also be afforded by the fact that its posterior portion is laterally in direct apposition to, and connected by membrane with, the cup-shaped tergite I have regarded as tergite 8.



Figs. 5–6.—*Carpophilus obsoletus.* (5) Male, eighth sternite and strut (ventral aspect). (6) Female genitalia, extended (ventral aspect). C.R., chitinised rod; 8, basal sclerotised ring (eighth segment); B, baculi; V, valvifer; P, paraproct (dorsal to structure); C, coxite; S, style.

FEMALE.

In the female abdomen there are seven distinct tergites and five sternites externally visible (fig. 2). As in the male, the first sternite is equivalent to the first three tergites after which dorsal and ventral plates correspond.

The ovipositor is developed posterior to the seventh segment and consists of the terminal segments greatly modified so as to produce a long flexible tube which in the resting condition lies folded within itself inside the seventh segment. It is differentiated into the following regions (fig. 6) :

(*a*) A basal sclerotised ring consisting of dorsal and ventral elements connected by membrane to the apex of the seventh segment. A long strut is attached to the ventral part of this ring by its posterior end. This is the "Chitinised Rod" of Metcalfe (1932) and Rakshpal (1947*b*).

(*b*) A long membranous tube enclosing the vagina and rectum attached basally to the sclerotised ring. The apical portion of this tube is termed the "Valvifer" and it is somewhat sclerotised, its surface being differentiated to form a pair of ventral and a pair of dorsal longitudinal rod-like thickenings—the " Baculi " of Tanner (1927). The valvifer terminates in the " Paraproct " and bears the genital appendages ventrally at its apex.

(*c*) The genital appendages articulating with the valvifer and consisting of a pair of proximal coxites and a pair of distal styli. The basal halves of the two coxites are fused together along the mid-line while the apical halves bearing the styli are free.

The morphology of the female genital structures is still unsettled. Parsons (1943) states that the basal sclerotised ring of the ovipositor is the modified 8th segment, and believes after various authors, notably Tanner (1927), that the valvifer is the 9th segment, the appendages, its coxites and styles, and the proctiger the 10th segment. This view as to the truly appendicular nature of the appendages is supported by Singh-Pruthi (1924*b*, *Tenebrio molitor*) and Metcalfe (1932, *Sitodrepa panicea* and *Gastroidea*). The former author showed them to be developed from a pair of appendages first evident in the larva, and the latter showed them to be derived from a pair of outgrowths of the ectoderm bordering the primary genital depression.

Rakshpal (1947*b*) considers the elongate membranous tube of the ovipositor to be the 8th segment, and although agreeing that the appendages are truly appendicular and derived from the 9th segment, he regards them as being the telopodites of that segment and not the coxites. He prefers the terms "Chitinous Pouch" and "Genital Palp " to " Coxite " and " Style."

There is disagreement concerning the origin of the median ventral chitinised rod. Metcalfe (1932, *Sitodrepa panicea, Anthonomus pomorum* and *Rhagium bifasciatum*) shows that it is produced first of all as an invagination of the membrane behind the 7th sternite. Rakshpal states that it is produced from the 7th tergite, but does not give details as to how it migrates from its original dorsal position to the ventral position evident in the mature insect.

The general arrangement of the female genitalia is shown in fig. 6, the nomenclature adopted being that of Parsons (1943) with the exception that the term "Chitinised Rod " is preferred to his " Spiculum Ventrale."

SUMMARY.

The external genital organs of both sexes of the Nitidulid beetle *Carpophilus obsoletus* Er. are described and figured, and the morphology and nomenclature of their various parts is discussed.

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A NEW AND SIMPLE METHOD OF DEMONSTRATING THE PHYSICAL GILL OF AQUATIC INSECTS.

By Edward J. Popham, D.Sc., Ph.D., F.R.E.S.
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As long ago as 1887 Comstock suggested that the air stores of aquatic insects might function as physical gills. This view was later supported by Hagemann (1910), Hoppe (1912) and Wesenberg-Lund (1913). The most important of later writers was Ege (1915), whose work placed the hypothesis of the physical gill upon a sound experimental basis. Ege's conclusion that the air stores of aquatic insects acted as physical gills was based upon two lines of evidence.

In the first place, he observed that when some aquatic Coleoptera or Hemiptera were confined in a vessel of water from which all gas bubbles had been excluded, the amount of dissolved oxygen in the water gradually declined. These observations have been confirmed by Ruiter *et al.* (1952) as well as Van der Heyde (1922). The fact that the insects absorb dissolved oxygen has been taken to indicate that the air stores carried on the surface of the insect function as physical gills. It is not unlikely that this is the true explanation, but as these authors have not mentioned the possibility of oxygen being absorbed through the cuticle, this line of evidence has not as yet produced a conclusive demonstration of the physical gill.

Ege's second type of evidence was to observe that *Notonecta* lived for five minutes in nitrogen saturated water, 35 minutes in oxygen saturated water and for seven hours in water saturated with air. These observations have been confirmed by Thorpe and Crisp (1947). The fact that the notonectids lived for such a long time in air saturated water does not necessarily prove that the oxygen has been absorbed through the air stores, which are normally carried on the surface of the insect, though this would appear to be the most plausible explanation of these observations. Ege's hypothesis of the physical gill is so plausible that the subject was left more or less uninvestigated for nearly forty years until it was taken up by Ruiter *et al.* (1952). There can be little doubt that Ege placed the hypothesis upon a strong experimental basis. It is, however, one thing to publish a plausible hypothesis and another to establish the veracity of that hypothesis beyond all reasonable doubt.

Some of what Ege wrote on the physical gill was not based upon either observations or experimental work. At times he allowed himself to be drawn into making speculations by appealing to the principles of physical chemistry. The work of Ruiter *et al.* (1952) has certainly shown that the physiology of aquatic insects does not necessarily follow the simple laws of the physical sciences. These workers showed that the efficiency of the physical gill could be greatly modified by various biological phenomena, such as the periodic movements of the hind limbs. The following statement may be cited as an example of Ege's speculations : " In the summer the animals examined except *Hyphydrus* and the smaller species of *Corixa*, can only get sufficient oxygen by invasion from the water during rest but not when active." Ege's paper contains no measurements of the oxygen requirements of active insects and

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the only corixid mentioned by name is *Corixa geoffroyi* (= *C. punctata*), which is one of the largest species of Corixidae. Elsewhere Ege writes " The nitrogen will, therefore, diffuse out from the supply of air into the water. During the animals' stay in the water the supply of air will decrease and finally disappear. This is the chief reason why the animals . . . cannot remain indefinitely in the water." Nowhere in Ege's long paper is there any evidence to show that the air stores of any aquatic insect disappear before it rises to the surface. Observations on almost any aquatic hemipteron or coleopteron will show that the insects normally rise to the surface before the air bubbles disappear.

The experiment described below was originally designed to provide a simple demonstration of the physical gill for teaching purposes, but in view of the inconclusive nature of some of Ege's experiments it may be of interest to a wider circle than the group of students for which it was originally intended.

EXPERIMENT DEMONSTRATING THAT THE AIR STORES OF AQUATIC INSECTS FUNCTION AS PHYSICAL GILLS.

In preparation for these experiments two large conical flasks were filled with water as far as the bottom of the neck. A small quantity of washed sand was added to each flask to provide a suitable substratum upon which the insects could settle. Each flask was closed by means of a rubber bung, which was pierced by two holes, in which were inserted lengths of glass tubing. One length of tubing reached nearly to the bottom of the flask. The other was much shorter and ended just below the bung. Both flasks were then heated over a bunsen flame and the water allowed to boil for several minutes in order to remove all traces of dissolved gas. After this a slow stream of oxygen was passed through one flask and a stream of nitrogen through the other. Then both flasks were allowed to cool to room temperature. The gases were allowed to pass through the flasks for several hours, after which the water was assumed to be saturated. The temperature of the flasks was 18° C. The long tubes leading the gas into the flasks were partially withdrawn until the lower end was no longer below the surface of the water.

The tube leading into the flask containing oxygen saturated water was then disconnected from the source of oxygen, and joined by means of a length of rubber tubing to the exit tube of the flask containing nitrogen saturated water. A stream of nitrogen now flowed through both flasks. Any oxygen present in the second flask would be swept away by the current of nitrogen, leaving the water rich in dissolved oxygen with a covering of nitrogen gas. The rubber bung of the flask containing nitrogen saturated water was raised for a few seconds while 12 specimens of *Corixa sahlbergi* (Fieb.) were introduced into the flask. While this was taking place a strong stream of nitrogen was passed through the apparatus to prevent the entry of air. The process was then repeated, and a similar number of corixids were introduced into the flask containing oxygen saturated water.

It is quite possible that the insects lost some of the oxygen in the gas surrounding them as they fell through the layer of nitrogen into the water. Any residual oxygen may either have been absorbed by the insects or have dissolved in the water. The former certainly occurred in both sets of insects, but the latter is only likely to have occurred in the flask containing nitrogen saturated water. The amount of oxygen which dissolved was probably so small that its influence can be ignored, as will be seen from what follows :

In the flask containing nitrogen saturated water the insects returned to the surface within a few minutes to renew their supplies of gas. After renewing their reserves, they dived for a second or a third time, and then returned to the surface within a few seconds. After five to ten minutes from the start of the experiment all the insects were floating motionless at the surface, and eventually died through lack of oxygen.

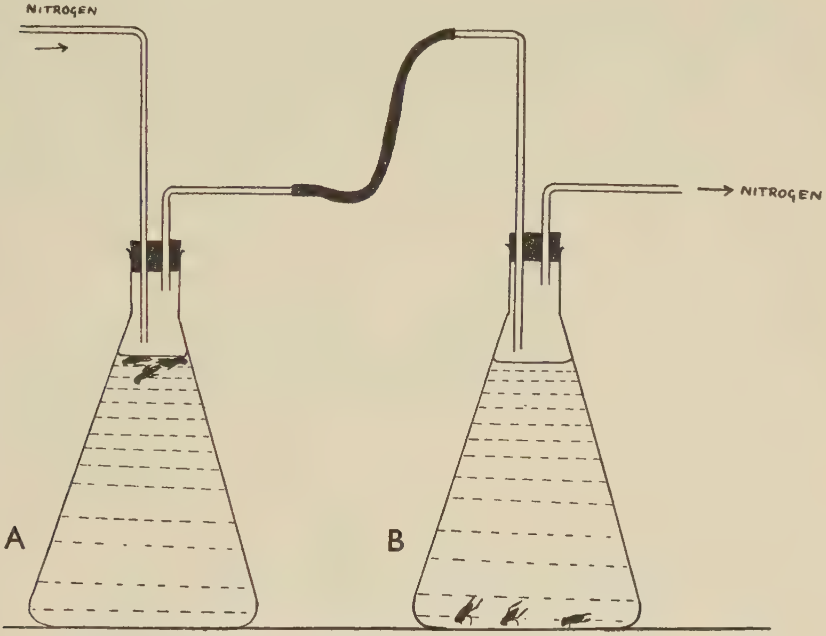

FIG. 1.—(A) Flask containing water saturated with nitrogen. Corixids floating dead at the surface within 15 minutes of the start of the experiment. (B) Flask containing water saturated with air or with oxygen. Corixids remain alive for several hours and behave quite normally.

In the experiment using oxygen saturated water, some of this gas probably passed out of solution into the gas space at the top of the flask. If this occurred the oxygen would be swept away by the current of nitrogen. Moreover, as the flask was filled with water to the bottom of the neck, the area through which the gas could escape was reduced to a minimum. On admitting the insects to this flask they swam to the bottom and remained there for several minutes before returning to the surface to replenish their reserves of gas. The experiment was continued for three to four hours, and throughout the whole of this period the corixids behaved in a perfectly normal manner. All the insects were alive and healthy when the experiment was brought to a close. Exactly the same result is obtained if the water is saturated with air instead of oxygen.

The fact that these insects remained alive, and did not die as did the insects in the flask containing nitrogen saturated water, showed that they could obtain sufficient oxygen for their needs. The only gas that they could obtain by visits to the surface was nitrogen. The only source of oxygen available to them was the oxygen dissolved in the water. This oxygen might be obtained through the skin in contact with the water or through the nitrogen bubble.

Inability of Corixids to Obtain Sufficient Oxygen through the Cuticle.

The abdominal spiracles of *Corixa* are situated on the ventral surface of the abdomen. The thoracic spiracles are less obvious, but are situated in shallow grooves ventral to the wings. These spiracles can be plugged with vaseline, which is applied by means of a sharp needle. This was done with the aid of a binocular microscope to ensure that the vaseline was applied to the minimum area possible. After this the corixids were placed in water, the wings were opened and any bubbles carried on the surface were dislodged with the aid of a needle. The corixids were then transferred to a vessel of water, which had been saturated with dissolved air at 18° C. They were tested one at a time, and were prevented from rising to the surface by holding one of the legs with a pair of forceps. At first the insects were quite active, but showed only feeble signs of movement after ten minutes. All were dead after 30 minutes. This shows that the corixids were unable to obtain sufficient oxygen through the cuticle to meet their requirements at 18° C. in air saturated water.

Conclusion.

In view of this second experiment there is only one possible conclusion to be drawn from the experiment described earlier in this paper; namely, that some of the oxygen dissolved in the water diffuses into the bubble of nitrogen and from thence passes into the tracheal system of the insects. In other words, the air stores of these insects function as physical gills.

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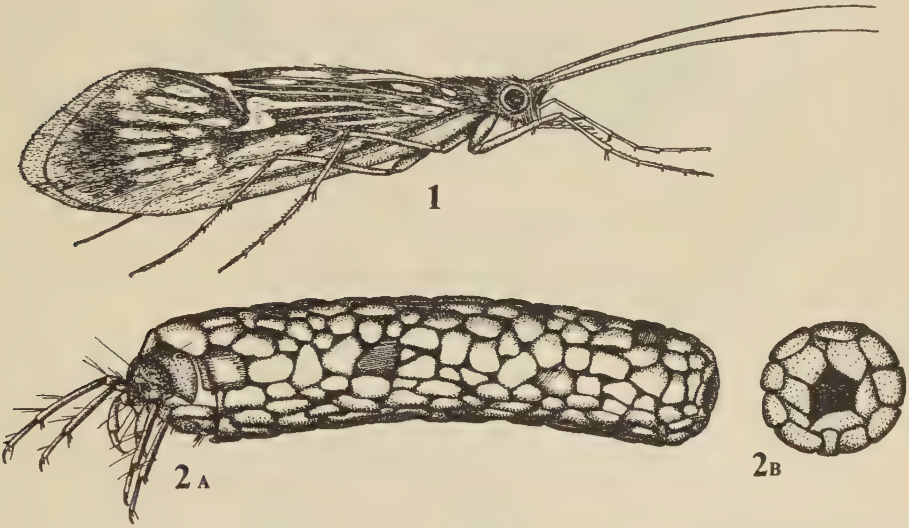
LARVAE OF THE BRITISH TRICHOPTERA.—41
STENOPHYLAX LATIPENNIS CURTIS. (LIMNOPHILIDAE).

By N. E. Hickin, Ph.D., F.R.E.S.

In July, 1951, I collected a number of caddis larvae from a small fast-flowing stream at Nutley in Ashdown Forest, Sussex, at about 300 ft. above sea level. From some of these I reared one of each sex of the species *Stenophylax latipennis* Curtis, Mr. D. E. Kimmins kindly confirming the identification. Again, on 21st August, 1952, I collected a number of pupal cases from the Nant y Bwch north of Capel-y-ffin in Brecknock at about 1400 ft. above sea level, from which one of this species emerged on 29th August. Mr. Kimmins who has reared this species from pupal cases obtained from a small stream draining into Lake Windermere (at about 130 ft. above sea level) believes that this species may be confined to the smaller streams, whilst *S. stellatus* Curtis may prefer the larger streams. This view is confirmed by my experience. For the purpose of this description I have re-examined my original material of *S. stellatus* and fresh larvae collected from Dowles Brook, Worcestershire, on 8th April, 1953.

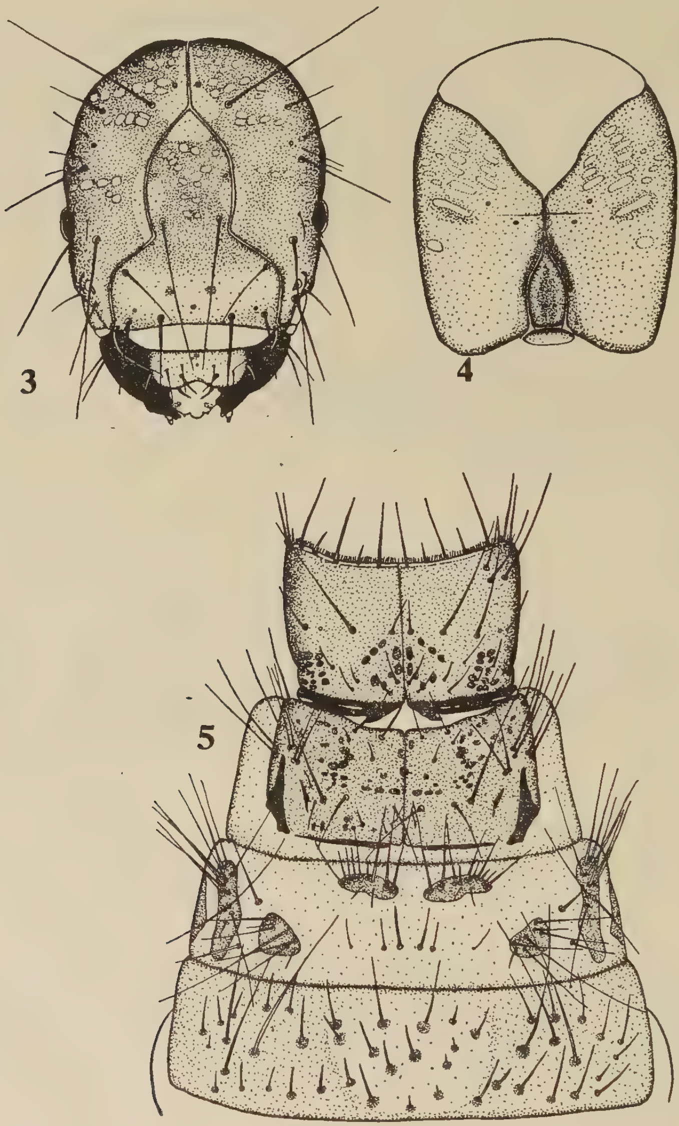


Figs. 1–2.—*Stenophylax latipennis* Curt. (1) Adult (length: head to wing tips 1 in.). (2A) Larva in case. (2B) Larval case from behind.

Larva.—So very like *Stenophylax stellatus* Curtis that great difficulty is experienced in separating it from this latter species. The patterns of dark marks on head and thoracic segments are so variable that no reliance can be placed on these. In *stellatus*, however,

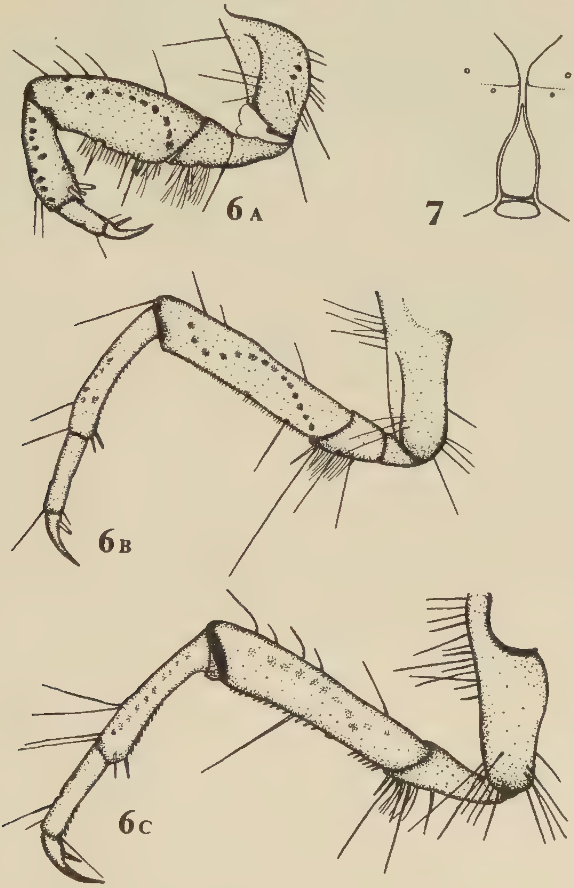
PROC. R. ENT. SOC. LOND. (A) 29. PTS. 4–6. (JUNE 1954).

the colour of the head is much darker than in *latipennis,* but when cleared in potash solution and seen from the front there is a light-coloured area on each gena near the genal suture, but separated from the latter by a dark band on each side. This light-coloured area is absent in *latipennis.* The genal suture on the ventral surface of the head is closed in *latipennis* but quite open in *stellatus,* while in both species the gular sclerite is darker than the surrounding genal areas except for the bounding folds. In all my specimens of *latipennis* the first abdominal segment is yelllowish-brown, whereas in *stellatus* it is grey.



Figs. 3–5.—*Stenophylax latipennis* Curtis. (3) Head of larva from the front. (4) Head of larva from behind. (5) Thoracic nota and first abdominal segment of larva.

A possible explanation of this, however, is that the stream from which I obtained the *latipennis* larvae is heavily charged with iron and the coloration of the first abdominal segment may be due to staining. Perhaps it is due to this that the small brown circular patches at the base of the spines and hairs on the first abdominal segment appear to be more pronounced in *latipennis* than in *stellatus.* The pale areas in the clypeus and the genae which have been given by previous authors as a means of identification are shown in fig. 3, but I am by no means satisfied that reliance on this character will give successful determination in every case. *Length* 20 mm., width 4 mm. *Case* : length 22 mm., width 6 mm. Slightly curved, flattened on ventral surface, almost uniform width when larva fully grown, of small stone chips. The cases of the Brecknock specimens were of small round pebbles and larger sand grains. Hinder end of case rounded and partially closed.



Figs. 6–7.—*Stenophylax latipennis* Curtis. (6) Legs of larva. A, pro-, B, meso- and C, metathoracic. (7) *Stenophylax stellatus* Curtis. Gular sclerite.

This species "congregates"—a number are found under one particular stone in the stream whereas apparently identical situations elsewhere are not favoured.

SUMMARY.

The larva of *Stenophylax latipennis* Curtis is described and figured. The adult is figured.

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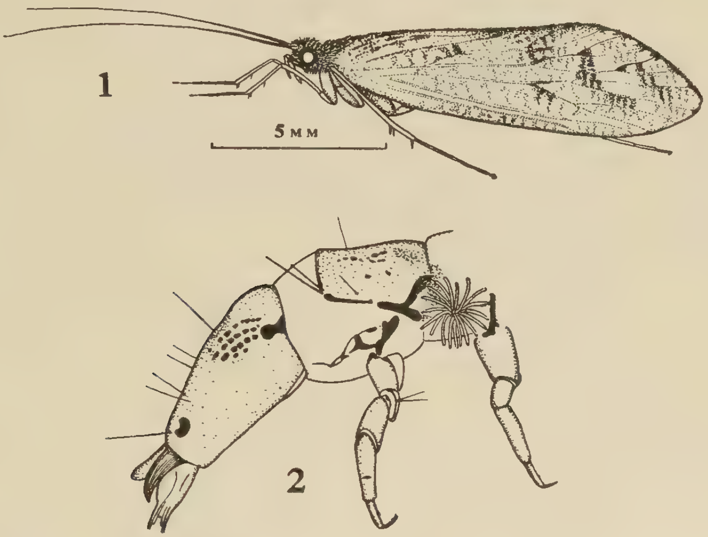
LARVAE OF THE BRITISH TRICHOPTERA.—42.
RHYACOPHILA SEPTENTRIONIS McLACHLAN (RHYACOPHILIDAE).

By N. E. Hickin, Ph.D., F.R.E.S.

I am very grateful to Mr. Arthur Peacey for conducting me on 5th April, 1953, to the secluded locality near Bisley, Glos., where in previous years he had collected the adults of this very local species. A small, but fast-flowing rivulet ran down to the main stream of the Battlescombe valley. The water was so heavily charged with lime that everything in the stream was encrusted, even the bag-like nets of *Philopotamids* were thick and brittle. Twelve larvae and two pupae of a *Rhyacophilid* were quickly found under stones where the stream ran fastest, and the subsequent comparison of these with Nielsen's description and figures showed them to be *Rhyacophila septentrionis* McLachlan. My drawing of the adult was made from specimens taken by Mr. Peacey from this same locality, and the wing pattern was checked with a specimen from the British Museum (Natural History) kindly made available to me by Mr. D. E. Kimmins.

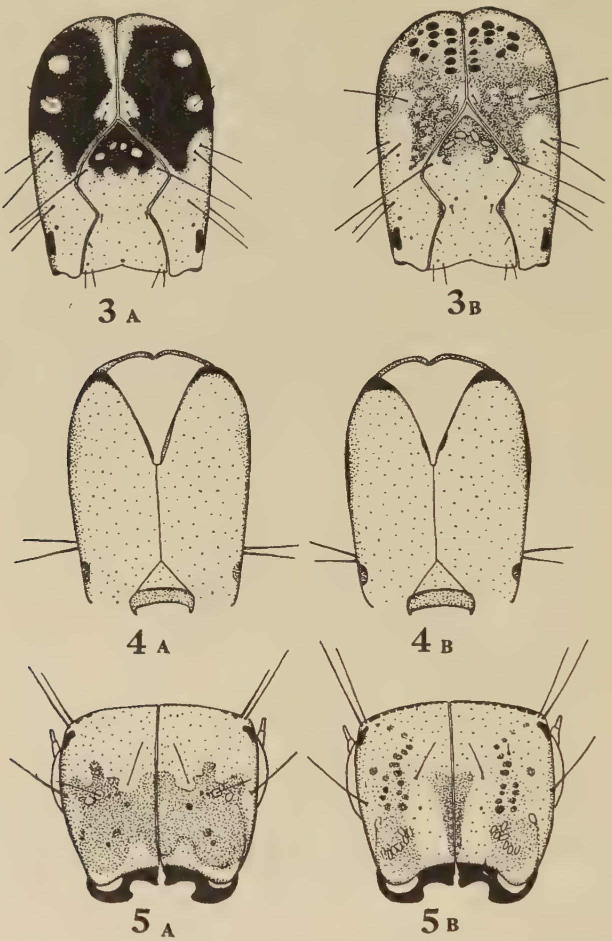


Figs. 1–2.—*Rhyacophila septentrionis* McLachlan. (1) Adult. (2) Larva, side view of head and thoracic segments.

The larva of *R. septentrionis* is very like that of *R. dorsalis*. There are, however, several well-defined differences, some of which can be picked up with a × 10 lens, thus enabling identification in the field. All my specimens of *septentrionis* were golden-olive in

PROC. R. ENT. SOC. LOND. (A) 29. PTS. 4–6. (JUNE 1954). 2§§§

colour, contrasting with the bright apple-green which is usual for *dorsalis.* In viewing the head from above, that of *septentrionis* is not nearly so heavily marked as *dorsalis,* and a pattern of brown spots occurs aborally and also laterally. This is absent in the latter species. In viewing the head from beneath, the aboral margins of the genae just before they become contiguous show a small fold, which is golden-brown in *dorsalis,* but jet black in *septentrionis.*



Figs. 3–5.—*Rhyacophila septentrionis* McLachlan. (3) Head from the front of larva of A, *R. dorsalis* ; B, *R. septentrionis.* (4) Head from below of larva of A, *R. dorsalis* ; B, *R. septentrionis.* (5) Pronotum of larva of A, *R. dorsalis* ; B, *R. septentrionis.* Mouthparts in figs. 3 and 4 are omitted.

The pattern of marks on the pronotum can also serve to differentiate this species from *dorsalis,* even though in both species there is a wide variation in marking, not only in pattern, but also in intensity. The larvae of *dorsalis* from which I made my original description were very lightly marked, so that I include in this paper some further drawings made from larvae of the more typical darker form. These latter were collected from the Dowles Brook at Furnace Mill, Cleobury Mortimer, Salop, on 8th April, 1953.

In *septentrionis* there is a triangular mark along the median suture with horn-shaped patterns of spots on each side. (The light areas between the former and the latter can easily be made out with a × 10 lens.)

In *dorsalis*, the dark lobar mass is continuous with a pair of projections on each side directed anteriorly, with a larger median projection between them. (Please note that in my original paper on *dorsalis* the drawing of the pronotum was reversed—the heavy black hook-shaped pieces are situated on the posterior margin of the pronotum.) The anterior margin of the pronotum is more heavily sclerotised in my specimens of *septentrionis* than in *dorsalis*.

SUMMARY.

The larva of *Rhyacophila septentrionis* McLachlan is described and figured, and a figure given of the adult.

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NOTES ON THE BIOLOGY AND WAXES OF FOUR SPECIES OF AFRICAN *TRIGONA* BEES (HYMENOPTERA : APIDAE).

By F. G. Smith, B.Sc.(For.)

(Beeswax Officer, Beekeeping Research Station, Department of Agriculture, Tabora, Tanganyika.)

In the Preliminary Report on *Trigona* wax (Smith, 1951) it was shown that the wax of stingless bees of the genus *Trigona* was used as an adulterant of beeswax, and was sometimes sold as beeswax. The samples of *Trigona* wax which were analysed were obtained from traders, and while it was believed that some of them were reasonably pure *Trigona* wax, there was always some element of doubt.

In order therefore to obtain samples of *Trigona* wax of known purity, a search was made throughout Central and part of Eastern Provinces for the nests of *Trigona*. Twenty-eight nests of the larger *Trigona* species were collected and examined, as well as numerous nests of the minute *Trigona* of the sub-genus *Hypotrigona*. As the quantities of wax present in *T.* (*Hypotrigona*) nests are insignificant, this sub-genus is not dealt with in this paper.

Of the larger *Trigona*, four separate species were found, and the adult insects and their nests are described herein. The wax obtained from these nests was sent to the Government Chemist in Dar-es-Salaam for analysis. Some samples were also supplied to Dr. Raymond, of the Colonial Products Advisory Bureau, and to Professor Tenniswood of the Department of Chemistry, Makerere College, for more detailed examination. Samples were also supplied to overseas firms, in order that they could determine whether there was an industrial use for *Trigona* wax.

In the descriptions of the species, particular attention has been paid to the nest, in particular to the formation of the brood nest. This is of the utmost importance when considering sub-generic divisions. Further, examination of adults found in nests has thrown much light on the question of varieties and sub-species. In the past, specimens caught on the wing having different coloration have been allocated to different varieties and sub-species, and in some cases to different species. Examination of nest material has shown that one queen can produce a wide range of colour variation in her progeny.

In nest material it is found that the newly emerged bees are pale. What will eventually be black areas are pale brown. Queens are usually in an intermediate stage. Further, these young bees will be found to have swollen abdomens which are believed to be due to the development at this stage of the wax glands. The older foraging bees, which normally find their way into the collector's net, are usually fully coloured and their abdomens shrunken.

Trigona denoiti Vachal.

Trigona "A."

Locality.	*Local Name.*
Kifiumi	Sache, Baarusehre.
Kiirangi	Ituvia.
Sandawe	Torongome.
Kinyamwezi	Ugaga.
Kigogo	Pula.
Kichagga	Nzii.

Distribution.

This is a common species, widespread throughout Eastern and Central Africa. It is reported from the Belgian Congo, Bechuanaland, and northern Transvaal, in addition to all parts of Tanganyika.

The nests were collected at Bonga in Mbulu District, Bereku, Chandama, Changalo, Mrijo and Kwa Mtoro in Kondoa District. Specimens of workers have been found in *Trigona* wax samples from Manyoni, Singida, Dodoma and Handeni.

Nests.

Near Bonga and Bereku the nests were in termite mounds on hill slopes. Soil, red to brown loam. Elsewhere in various soils, usually, but not necessarily, in termite nests. Entrances may be merely a hole approximately one centimetre in diameter, or a vertical waxy pipe, or a horizontal pipe along the surface of the ground made of wax, resin and earth particles. Up to eight nests have been observed in one termite mound and natives report that they have found up to twelve.

The termites appear to treat the *Trigona* as indifferently tolerated guests or synoekets. When the nests have been disturbed both the termites and the bees rapidly build protective walls of earth round their respective nests. If a bee should fall among the termites it is immediately attacked. The termites do not seem to attack the exposed *Trigona* nest, though stray termites may wander in, only to become entangled in sticky wax.

The nests are frequently located three-quarters to one and a half metres from the surface in close proximity to the brood and fungus galleries of the termites. It is possible that such a situation is chosen to ensure that a constant temperature is maintained in the bees' nest. The nest is connected at the top to the surface by means of a vertical or sloping pipe, average diameter one centimetre. From the bottom of the nest another pipe descends half a metre or more and finishes in a dead end. This pipe appears to act as a drain for any water that might enter or be produced by condensation inside the nest. The nest space and the entrance and drainpipes are lined with a hard black resinous material approximately 1 mm. thick. As a rule, the older the nest the thicker the lining.

The nest is an elongated pear shape, varying in size but normally about 15 by 20 cm. The narrower end is either at the top or to one side, and contains most of the honey and pollen pots. The more bulbous end contains the brood nest. The brood nests encountered contained up to fourteen combs surrounded by a labyrinthine involucrum of thin leaves of brown wax. The under side of the involucrum above the drainpipe area has a slightly mildewed appearance. The nest may be as much as two and a half metres below ground.

The honey and pollen pots are composed of thin brown wax and are either closely appressed or separated by pillars of wax. They are all of one approximate size, being oval, 1·5 cm. high and 1·0 cm. in diameter, when complete. The pots are irregularly arranged, pollen and honey being located at random. Among the food pots were observed two or three pots containing debris, probably discarded larval skins. Numerous white mites were seen among the debris.

Large elongated plugs of sticky wax are located just inside the nest close to the entrance and drain pipes. The largest is by the entrance pipe. It is thought that this sticky wax is used either for plugging the entrance in an emergency, or for plastering on to invaders, thus glueing them to death. Sticky wax plugs were found in position in the drainpipes in some nests.

The brood nest is composed of ten to fourteen combs separated by pillars of wax. The combs are round and frequently of spiral formation. The smallest and newest combs are at the top. Usually there is a central vertical hole, containing queen cells if these are present. Pillars in this axial region are dichotomous. Queen cells are also found at the outer edges of the brood combs. Brood cells containing eggs and young larvae are composed of brown wax. Cells containing older larvae and pupae have the wax removed from the ends, which are at that stage composed of larval skins. Most of the cells containing young brood are sealed, but occasional cells containing small larvae are left open. It is suspected that these are drone larvae. Brood development in each comb is rotational. As mature bees emerge, the cells from which they come, composed of larval skins, are removed. A gap is thus left in the ring of the brood comb. At the other side of the gap new cells of wax are built and provisioned. Continuing in an anti-clockwise direction round the comb, brood in increasingly advanced stages of development is encountered until return to the point where the bees are emerging. Brood development is not at the same stage in the other combs at points vertically above and below. The lower combs are always a little more advanced than the upper combs, so the gap between emerging brood and new brood cells proceeds in an anti-clockwise direction as it ascends. It is on this spiral stairway of new cells that the queen performs her task of egg laying. The largest brood combs are about 100 mm. in diameter. The vertical axial hole is 10 to 12 mm. in diameter, unless queen cells are present, when it may be up to 20 mm. Each comb is 5 mm. thick, this being the depth of the brood cells. In a straight run of 50 mm. on the surface of the comb there are 17 to 17·75 worker or drone cells. Queen cells are between 8·5 and 10·0 mm. long.

In one nest at Chandama there was no brood at all present though an involucrum had been constructed. The drones were engaged in massed flights. The presence of a virgin was suspected but not confirmed. There was no sign of a fully developed queen.

Diagnostic Characters.

Nest subterranean, generally in termite nest. Brood nest having spiral stair-case development. Workers with variable yellow facial maculations, thorax black, abdomen variable in coloration. Mandibles with two teeth ; teeth not prominent and are separated by a wide shallow cleft. Hind tibia with simple hairs ; sub-triangular in shape ; apical corners acute.

Trigona togoensis Stadelmann.

Trigona erythra var. *togoensis* Stadelmann.
Trigona " *B.*"

Locality.	*Local Name.*
Kigogo . . .	Mrego.
Kiirangi . . .	Mbuju.
Kinyamwezi . .	Upula.
Sandawe . . .	Isna.
Kichagga . .	Rungu.

Distribution.

In addition to East Africa this species is reported from Kabinda in the Belgian Congo. The writer has encountered nests in Kondoa and Manyoni Districts of Central Province of Tanganyika. Specimens were caught on Mango blossom at Illonga, Killosa District, Eastern Province, and the species is well known in the woodlands of Western Province. Workers have also been found in *Trigona* wax samples from Dodoma, Singida, Kondoa, Handeni and Tabora Districts.

Nests.

Normally found in the hollow trunks and branches of large trees. Morstatt (1921) reports that the Wachagga on Kilimanjaro sometimes find them in their beehives. The entrances are not normally conspicuous, but the hole may be surrounded by resinous matter.

The entrance is connected to the nest by a resinous tube to the nest cavity. The nest is very variable in size and shape, according to the space available in the tree. Generally the food cells surround the nest and the pollen and honey pots are arranged at random. The food pots vary in size between 1·5 and 2·0 cm. in diameter and between 2·0 and 2·5 cm. in height. In these nests were found one or two heavy irregular lumps of cream coloured material, whose composition has not yet been determined.

The brood nest is surrounded by a waxen leafy involucrum and contains up to fifteen horizontal combs, each of a single layer of brood cells. The largest comb measured was 10 cm. in diameter. The comb spacing, centre to centre, is approximately 9·0 mm. The thickness of the combs, which is the same as the depth of the worker cells, is between 5·7 and 5·8 mm. In a straight run of 50 mm., there are an average of 14 brood cells. The queen cells, which are located either at the edge of the brood comb or in the involucrum, are 9·0 to 9·2 mm. long.

The brood development differs from *T. denoiti* in that there is no spiral formation of the brood comb, and that egg laying commences in the centre of each comb. The largest and most developed combs are at the bottom, and each one above is successively smaller, the eggs and youngest larvae always being round the outside of each comb. The development of the brood nest therefore proceeds upwards in a conical form. The new cells are added to the top and sides of the cone. This continues until the fully developed brood commences to emerge from the centre of the lowermost comb. When a space is formed by the removal of the old larval skin cells, the queen returns to the bottom of the nest and commences a new cone of brood combs in the space. A gap is left between the rings of emerging brood and the cone of young brood. This space often has, in addition to the usual waxen pillars, a partial involucrum screening the old brood from the new.

That this species is well able to defend itself in spite of lack of an effective sting was demonstrated by a colony that had been transferred from a tree and put in a box in the writer's garden. Honey bees, *Apis mellifica*, attempted to rob the stingless bees' nest. However, they did not succeed, as the *Trigona* set upon the honey bees, seizing the leading edges of the bees' front wings with their mandibles. The bees were unable either to sting or bite the *Trigona*, which hung on like bull dogs until the honey bees retreated.

Diagnostic Characters

Nest arboreal. Brood nest having horizontal combs with conical development. Head and thorax of worker black and pitted. Mandibles with two prominent teeth, separated by a deep cleft. Hind tibia broad, with simple hairs and a spoon-shaped excavation. Posterior apical corner rounded.

Trigona beccarii Gribodo.

Locality.	*Local Name.*
Kiirangi	Itula ngombe.
Sandawe	Terengombe, Nachto.
Kikonyonga	Kwimba.
Kikimbu	Ipilia.
Kisumbwa	Kililu.

Distribution.

A common species widespread throughout East and Central Africa. The type of this species was collected by Beccari at Keren. Other specimens have been collected in Martini's Concession, Eritrea. Varieties are reported from the Belgian Congo, Nyasaland, and Benguella. The writer has collected workers in Kondoa, Iringa and Songea Districts of Tanganyika, in addition to nests at Lalta, Kondoa District. Although the above species and varieties would appear to be races of *T. beccarii*, examination of nest material is required to establish true relationship.

Nests.

Found in the ground down to one metre. Some are so close under the surface that cattle put their feet into them, sometimes breaking their legs. The honey badger, *Mellivora sagulata* Hollister, is said to dig up the nests for the honey and brood.

A black tunnel leads down from a simple entrance hole to the top of the nest cavity. The storage pots surround the brood nest, but are mostly on top. The storage pots are between 2 and 2·5 cm. in diameter and 3 cm. high. The involucrum contains horizontal brood combs showing the same conical form of development as with *T. togoensis*. The largest brood combs encountered were 9 cm. in diameter. The thickness of the combs is 7 mm. Queen cells 9·5 to 10 mm. long. In a straight run across the surface of the brood comb of 50 mm. there are 12·5 brood cells. Inside the involucrum, at the bottom of the brood nest, was found the nest rubbish, larval skins and other bits and pieces. Rubbish pots, as found in nests of *T. denoiti* were not seen. Queen cells were found hanging from combs suspended by wax attachment.

Diagnostic Characters.

Nest subterranean. Brood nest having horizontal combs with conical development. Yellow maculations on face and lateral margins of mesonotum and on scutellum. Yellow marks and bands on abdomen interrupted dorsally. Reddish hairs on head and thorax. Wings with reddish tinge. Mandibles with two teeth which do not protrude beyond the line of the straight cutting edge. Excavation in hind tibia flat and extending over the apical three quarters.

Trigona staudingeri Gribodo.

Locality.	*Local Name.*
Kilosa	Pumi.
Kiirangi	Mbosho.
Kichagga	Inyeri.

Distribution.

Highly local in its occurrence in East and Central Africa. In the places where it does occur it appears to be abundant. Outside Tanganyika it has been reported from Kabinda in the Belgian Congo. The writer has collected nests at Ilonga, near Kilosa, Eastern Province, and has seen a nest near Korogwe. Nests of this species had been reported by natives near Morogoro, at Arusha-chini, south-east from Kilimanjaro, and on the Makonde Plateau, Southern Province.

Nests.

The nests of this species are found externally on the undersides of the branches of trees. The nest itself is externally coated with plates of cerumen. Within the outer skin is a labyrinthine wall of cerumen, 3 to 5 cm. thick. The entrance area is towards the bottom of the nest. The entrance merely consists of a thickening of the labyrinthine wall and absence of outer plates. The brood nest, which is surrounded by a thin involucrum of brown wax, is located in the upper part of the nest. The honey, pollen and gum pots are at the sides and below the brood nest. The pots are fairly small, often no more than 1 cm. high.

The form of the brood nest shows the highest degree of development in the genus *Trigona,* assuming that *Apis* has reached the highest state of all bees. The brood combs hang vertically, are built from the top downwards and are double sided. This form is unique among the Meliponidae. The New World species, and as far as is known, all the other Old World species, build either single layer horizontal combs or merely irregular clusters of brood cells. The combs do not hang parallel to each other but in irregular folds. The brood nest does not develop in the form of a rough sphere extending outwards in concentric layers as in *Apis.* Instead, the queen starts laying at the top in the newly built cells, and at the same horizontal level in each comb. The bottoms of the combs are therefore level and contain the newly laid eggs. The upper parts of the combs contain more advanced brood, all at the same stage of development at each horizontal section. As the fully developed bees emerge from the uppermost cells of each comb, the cocoons of larval skins are removed and replaced by an open structure of branching wax pillars. Above this pillar structure new brood cells are built and provisioned. The horizontal space containing the wax pillars is thus constantly moving downwards as mature bees below it emerge and new cells above it are being built. When the brood at the top of the brood nest starts emerging, the queen returns to the top of the brood nest and begins again. The double sided combs are approximately 1 cm. thick. In a straight run of 5 cm. on the surface of the comb there are 14·5 worker cells. Queen cells are found in any part of the brood nest and are 7 to 8 mm. long and about 5·5 mm. in diameter.

In addition to the thick labyrinthine wall of cerumen surrounding the whole nest, there are a number of wax pots containing a brown sticky waxy substance. When disturbed, the bees arm themselves with pellets of this sticky substance on their hind tibia and fly to the attack in large numbers. The foe is well bitten by their tiny but sharp mandibles, and smeared with sticky ammunition. Even human beings find this treatment highly demoralising as not only is the skin covered with sticky biting bees, but also ears, nose and eyes are fully investigated. The sticky wax is also placed on the surface of any damaged portion of the nest, thus presenting an effective barrier against ant attack.

Diagnostic Characters.

Nest extra arboreal. Brood combs vertical, double sided, horizontal downward development. Bees black, thin, elongated. Legs very thin except for wide rounded hind tibia. Plumose hairs on legs.

TRIGONA WAX.

As the laboratories of the Beekeeping Research Station are not yet completed, most of the nests were sent to the Government Chemist, Dar es Salaam for analysis. Nest material was also supplied to the Colonial Products Advisory Bureau (Plant and Animal), in London, and to Professor Tenniswood of the Makerere College. The results of the analysis are summarised below.

The wax of sixteen nests of *Trigona denoiti* was analysed, and found to fall within the following ranges :

	(1)	(2)
Saponification value	8·3–39·5	.
Acid value	5·6–8·5	7·5
Ester value	2·7–30·5	36·9
Iodine value	47·5–54·8(*a*)	73·8%(*b*)
Specific gravity	0·952–0·975	.
Setting-point	62·5–66·5	.
Melting-point	.	66·4
Refractive index 80° C. N_D	.	1·4687
Weinwurm test	Positive	.
Sterol group test	,,	.

Column (1) shows the range within which the 13 nests analysed by the Government Chemist fall. Column (2) shows the results obtained by the Colonial Products Advisory Bureau from a cake of wax obtained from these nests.

(*a*) Hanus ½ hour. (*b*) Wijs 3 hours.

The wax of two nests of *Trigona togoensis* gave the following results :

Saponification value	31·0–53·5
Acid value	2·8–8·5
Ester value	28·2–45·0
Iodine value	48·2–50·6(*a*)
Specific gravity	0·958–0·970
Setting-point	57·7–65·0
Weinwurm test	Positive
Sterol group test	,,

Two nests of *Trigona beccarii* were as follows :

Saponification value	44·4–46·8
Acid value	6·15–9·9
Ester value	34·2–40·65
Iodine value	54·6–55·6(*a*) 98·3%(*b*)
Specific gravity	0·962–0·965
Setting-point	61·0–64·0
Melting-point	64·6°
Refractive index at 80° C. N_D	1·4625
Weinwurm test	Positive
Sterol group test	,,

(*a*) Hanus ½ hour. (*b*) Wijs 3 hours.

Analysis of one nest of *T. staudingeri* produced the following results :

Saponification value	49·9
Acid value	12·9
Iodine value	55·8(*a*)
Specific gravity	0·972
Setting-point	61·3°
Weinwurm test	Positive

The Sterol group test used is that of Liebermaun-Burchard. *Trigona* wax gives a red to reddish brown colour, while beeswax gives a greenish colour.

There were insufficient results to show any significant difference between the waxes produced by the different species of *Trigona*.

The range of values into which pure *Trigona* wax would appear to fall is as follows :

		Average.
Saponification value	8·3–53·5	33·6
Acid value	2·8–12·9	7·0
Ester value	2·7–45·0	27·1
Iodine value	47·5–60·9(*a*)	50·1
Specific gravity 15·5/15·5° C.	0·952–0·975	0·963
Setting point	57·7–66·5	63·8
Ratio No.	0·5–10·0	4·4
Refractive index 80° C. (2 samples) N_D	1·4625–1·4687	.
Weinwurm test	Positive	.
Sterol group test	,,	.

(*a*) Hanus ½ hour.

ACKNOWLEDGMENTS.

The author is indebted to Mr. Herbert F. Schwarz, of the American Museum of Natural History, for naming specimens of *Trigona*. Grateful thanks are also due to Mr. Calton, the Government Chemist, and to Dr. Raymond of the Colonial Products Advisory Bureau, for carrying out the analysis of samples of *Trigona* wax sent to them by the writer.

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NOTES ON FURTHER PARTHENOGENETIC GENERATIONS OF A SPECIES OF *MESOCELIS* (LASIOCAMPIDAE) FROM THE EASTERN KAROO.

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In an earlier paper (Taylor, 1950), an account was given of a species of *Mesocelis* (Lasiocampidae) occurring in a restricted area of the eastern Karoo. The species involved, known as the Karoo *Mesocelis*, proved to be of exceptional interest, in that it exhibited obligatory or constant parthenogenesis. During a period of four years, up to and including 1949, four parthenogenetic generations had been reared, the progeny of each successive generation being entirely female. Breeding and field work have been continued since 1949, but before proceeding to record the results, it may be helpful to repeat the summary of the previous paper.

" (1) An account is given of the life-history and habits of a species of *Mesocelis* (Lasiocampidae) occurring in a karroid area of the Eastern Cape Midlands, together with descriptions of the various stages.

(2) The Karoo *Mesocelis* is compared with *Mesocelis montana* Cram., and the evidence suggests that it belongs to at least a subspecies or different race of the latter.

(3) The male of the Karoo *Mesocelis* has not hitherto been found, in spite of continued research. Successive generations of virgin females have reproduced vigorously, and it would therefore appear to be a case of obligatory parthenogenesis.

(4) The literature on parthenogenesis in Lepidoptera is briefly reviewed, as well as discussed in relation to the Karoo *Mesocelis*."

To this, it may be added that *Mesocelis montana* is widely distributed in Southern Africa, having been recorded from the Cape Peninsula, Algoa Bay, Little Namaqualand, the Orange Free State, the Transvaal and Rhodesia. For a full account of its life-history and habits, reference may be made to Hesse (1935).

It was also stated in the earlier paper than although there are many resemblances between the Karoo *Mesocelis* and *M. montana*, the differences are sufficiently marked as to be thought of some significance, possibly even specific. Thus all stages, namely egg, larva, pupa and adult female, are considerably larger in the case of the Karoo *Mesocelis*, in addition to the other structural differences now briefly summarised as follows: With the Karoo *Mesocelis* the egg is oval and is not narrower at one pole as in *M. montana*, while the larva of the former differs in the colour of the legs; the absence of markings on thorax and abdomen; the absence of black fasciae on the head in the final instar; and in fewer white hairs antero-laterally. Also, there is but one pattern of larva, but in *M. montana* those destined to be female adults differ both in appearance and size from the potential males. The wing lobes are barely discernible on the pupa of the Karoo form, while in *M. montana* they are described as not extending to or beyond the middle of the body (Hesse, *op. cit.*). In the adult female, there is little difference apart from size, but with *M. montana*, the male sex is of regular and normal occurrence, whereas in the Karoo *Mesocelis* it remains unknown. There are also differences in seasonal history and in host-plants. " It would therefore seem," to quote from the previous paper, " that the Karoo *Mesocelis* is at least a subspecies of *M. montana*, if not a different species altogether."

Investigations since the publication of the previous paper have proceeded as before, namely breeding work at the laboratory, supplemented by data obtained, and collections of larvae made annually, in the field. It may here be recalled that the species is univoltine. Four further generations have now been reared from the stock originally obtained in 1946, making a total of eight generations reared, all of which have been parthenogenetic. An account of the investigations since 1949 follows, but in order to make it more complete and connected, it is necessary to include, from time to time, data published before.

Distribution and Occurrence.

In the earlier paper, the area in which the Karoo *Mesocelis* occurs was stated to be some 18 miles long by a few in width, extending from the town of Pearston to the Jansenville district boundary. It has recently been found to be somewhat larger than was originally supposed : it includes the more or less flat plain which lies to the west and south-west of Pearston for some 25 and 20 miles respectively, as well as for some eight miles to the east of that town. As far as we know at present, its range does not extend further, and it has never been seen in the hilly country bordering the plain mentioned above. While, therefore, the area of its distribution is somewhat larger than was first thought, it would still appear to be considerably restricted.

Even within the area of its known distribution, the occurrence of the Karoo *Mesocelis* is somewhat local and sporadic. Thus, it was originally found plentifully in 1944 on the Pearston commonage within a mile or two of the town, and up to and including 1950 no difficulty was experienced in collecting larvae there. In 1951, however, larvae were scarce in the field, and very few were to be found anywhere, despite widespread search in the vicinity of the original site and elsewhere. In the following year, 1952, larvae were more plentiful, but only at a distance of some five to six miles from the original site and in the direction of Jansenville, while in 1953 they were again numerous at this same place. During both these years, only a few odd individuals were observed where they had originally been found in 1944, and had continued to be at least fairly plentiful until 1950. The reason for this disappearance from the original site is not clear, as there has been little apparent difference in the quality and quantity of the host-plant at the two places.

The incidence of the larva also continues to vary very considerably from year to year, and in some years it occurs much more abundantly than in others. During seasons in which there have been copious rains in autumn (April–May), the larva would appear to be more plentiful, and this is also reflected later in egg production. With an abundant supply of suitable food for the larvae, the egg output of the resulting females is larger. Similarly where the insect has been released at Fort Beaufort, over 100 miles from its original home. With ample and succulent food supplies, it thrives and multiplies, but under drought conditions it tends to disappear. In this connection, it may be mentioned that at Fort Beaufort the normal host-plant *Ruschia* sp. (Ficoideae) does not occur, and the larva feeds mainly, both in cages and under field conditions, upon species of *Mestoklema*, a very different and less drought-resistant genus of the same family. This may be at least partly responsible for the fact that cage-reared material is usually somewhat smaller in both size and egg output than field material from the natural Karoo habitat. The principal limiting factors continue to be climatic, parasites and predators apparently playing a relatively minor part.

BREEDING DATA.

A total of eight generations has now been reared parthenogenetically, and a high percentage of the eggs has continued to be fertile. Although this has varied from 96·8 per cent. to 82·6 per cent. and the percentage of hatching from 92·3 per cent. to 66·8 per cent., the variation is not thought to be due to continued parthenogenetic breeding, but rather to extraneous factors, such as those of a climatic and nutritional nature outlined above. Thus in 1949 and 1953, when percentages of hatching were low (and fertility also in 1953), the food supplies had been suffering from drought. The figures for fertility and hatching for six successively reared parthenogenetic generations since 1947–48 are given in Table I below.

TABLE I.—*Fertility and Hatching of Eggs: Reared Generations.*

Year.	Number of eggs.	Number fertile.	Percentage.	Number hatched.	Percentage.
1948	2620	2496	95·3	2420	92·3
1949	2144	1951	91·0	1433	66·8
1950	3463	3277	94·9	3053	88·2
1951	3097	2999	96·8	2684	86·8
1952	1537	1379	89·7	1301	82·0
1953	1559	1288	82·6	1075	69·0

In Table II, which follows, the corresponding figures for field material, collected in the late larval instars, during the four seasons 1949–50 to 1952–53 are given. If this table be compared with the preceding one, it will be seen that the percentages of both fertility and hatching are somewhat higher than in the case of the reared material, but that they nevertheless fluctuate, although not to the same extent. The higher fertility and hatching rates, as suggested earlier, are probably due to the more natural conditions, including the normal host-plant, obtaining during the greater part of the larval period.

TABLE II.—*Fertility and Hatching of Eggs: Field Material.*

Season.	Number of eggs.	Number fertile.	Percentage.	Number hatched.	Percentage.
1949–50	960	903	94·1	815	84·9
1950-51	3752	3705	98·8	3575	95·3
1951–52	566	532	94·0	501	88·5
1952–53	3017	2920	96·7	2488	82·5

In Table III of the previous paper (Taylor, *op. cit.*), the number of eggs per female from both reared and field material were indicated for the years 1945 to 1949. The results obtained since then are very similar, and are given in Table III below.

TABLE III.—*Number of Eggs per Female.*

Year.	Number of females.	Total number of eggs.	Number of eggs per female.	Average number of eggs per female.	Source.
1950	20	3463	125–209	173·1	5th gen. reared.
1950	6	960	115–190	160·0	Field larvae.
1951	12	3097	202–312	258·1	6th gen. reared.
1951	12	3752	222–244	312·7	Field larvae.
1952	12	1537	103–163	128·1	7th gen. reared.
1952	3	566	106–241	188·7	Field larvae.
1953	12	1559	103–163	130·0	8th gen. reared.
1953	12	3017	124–411	251·4	Field larvae.

With reference to the sixth column (headed " Source ") of this table, it should be explained that " gen. reared " indicates adults reared parthenogenetically in cages.

From this table it would appear that the egg output from field material is generally greater than that from artificially reared material, the average number of eggs per female being 251·4 and 172·4 respectively, and the reasons for this discrepancy have already been discussed. In this connection, it may be pointed out that in the season 1950–51, when the egg output for both field and reared material was particularly high, only once before having been exceeded in the case of the former, and never hitherto in the latter, the supply of succulent food was luxuriant and abundant, thanks to the copious autumnal rains which then occurred.

DISCUSSION.

The Karoo *Mesocelis* has been under investigation since 1945, and eight generations in all have been reared in cages, while collections of larvae and/or pupae have been made annually in its known habitat in the Pearston district of the Karoo. The habits and life-history of this lasiocampid have been given in an earlier paper (Taylor, *op. cit.*), and the subsequent investigations of the last four years, both in the laboratory and in the field, have not added any new data in this respect. They have, however, confirmed the conclusion then offered that we are here dealing with a case of obligatory parthenogenesis, as defined by Cockayne (1938). Up to the present, the male of the Karoo *Mesocelis* has not been found, despite the fact that the cocoon is designed for male intervention, and closely resembles in structure the cocoon of *Mesocelis montana*, differing from it only in size. All eight generations reared since 1946 have been entirely parthenogenetic, the female moths concerned having been obtained and kept under cage conditions throughout. Similarly with material collected annually in the field ; no male or trace of the male, other than the cocoon structure, has ever been found, and it seems probable that this state of affairs has existed for many years. Despite the absence of the male sex, however, the female continues to reproduce successfully, and although the percentage of fertility of the eggs fluctuates somewhat, it remains relatively high. The fluctuations are thought to be due to seasonal variations in the state of the food supply of the larva, and not to any physiological weakness through continued parthenogenesis. The average percentage of fertility for the eggs of the reared parthenogenetic generations is approximately 92 per cent., while that for the last four generations of field material is 96 per cent. Breeding work has now been abandoned, but it is intended to continue with field collections in the hope of yet obtaining the male, although the chances of success would seem to be remote.

As pointed out by Cockayne (*op. cit.*), and quoted in the earlier paper on the Karoo *Mesocelis*, obligatory parthenogenesis is well-known in the Psychidae and Tineidae, and in some of the species concerned, males are not known to occur, while in others there are both bisexual and parthenogenetic races. In other families of the Lepidoptera it would appear to be unusual. The only known analagous case to the one under discussion, also referred to by Cockayne (*op. cit.*) and quoted in the previous paper, concerns *Orgyia dubia* Tausch. (Lymantriidae). This species is normally bisexual throughout the greater part of its range, but in one area of Southern Russia the larvae are unusually large and give rise to correspondingly large females. The latter are entirely parthenogenetic and the male sex is unknown. This case agrees very closely with that of the Karoo *Mesocelis* and *Mesocelis montana* in which there are marked differences in the size and structure of the various stages. In the Karoo *Mesocelis*, it would appear that the male sex has been eliminated, but that it existed at one time seems evident from the structure of the cocoon. In its absence, however, the systematic position of the insect involved must remain uncertain.

Summary.

An account is given of a case of obligatory or constant parthenogenesis occurring in a species of *Mesocelis* (Lasiocampidae) found in a restricted area of the Cape Midlands section of the Karoo. Earlier work on the subject, published in a previous paper, is briefly reviewed and discussed in connection with more recent investigations.

Acknowledgment.

The writer is deeply indebted to Dr. John Hewitt, Albany Museum, Grahamstown, for interest shown throughout, and for much helpful advice and criticism in the compilation of the manuscript.

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MICROMUS VARIEGATUS FABRICIUS (NEUROPTERA) AS A PREDATOR OF THE PEA APHID.

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In the course of biological and population studies on the pea aphid *Acyrthosiphon pisum* Harris, many fields of lucerne, hop trefoil, clover and sainfoin have been swept. The crop in any one of these fields could have been described as " low herbage " and hence could have constituted the type of habitat given by Killington (1936) as being suitable for the not uncommon lacewing, *Micromus variegatus* Fab. (Plate 1*a*), especially when there were often large numbers of pea aphids present. It is surprising, therefore, to find that, whilst adults and larvae of *Chrysopa* spp. frequently appeared in pea aphid samples, *M. variegatus* was only recorded twice prior to 1952. Both of these previous records were obtained in 1949 from the same field of lucerne at Sawbridgeworth, Herts., and on neither occasion could *M. variegatus* be considered a predator of any importance in the control of the pea aphid, as can be seen from Table I.

Table I.

	Numbers in 25 standard sweeps.	
Date.	*M. variegatus.*	Pea aphids.
7.viii.49 . .	3	1,454
20.viii.49 . .	1	19,039

In 1952, however, records from a field of lucerne at Wellesbourne, Warwickshire, showed that *M. variegatus* could feature much more prominently as a controlling agency of the pea aphid than had previously been thought to be the case.

Field Observations.

The field at Wellesbourne was sampled periodically throughout 1952 and the pea aphid and predator populations were assessed on each occasion. These samples showed that the aphid population was never very high and insufficient to attract a large number of predators. Coccinellids and syrphids appeared first and were present in average numbers, whilst anthocorids were fairly numerous in the first half of July.

On 23rd July *M. variegatus* adults occurred, and were the only predators found on that occasion. Furthermore, on that date, *variegatus* was numerically greater than was any other predator at any one time throughout the year. Six days later this lacewing was still quite as abundant but by this time adult 14-spot ladybirds, *Propylaea quatuordecimpunctata* Linn., were also present.

Table II gives the number of aphids and predators taken in 25 standard sweeps on 23rd and 29th July.

TABLE II.

Date.	Numbers in 25 standard sweeps. Pea aphids.	*M. variegatus* adults.	Other predators.
23.vii.52 . .	372	21	.
29.vii.52 . .	268	19	8 14-spot ladybirds

The reduction in aphid numbers in the lucerne crop between the two dates shown in the table, can be attributed to a combination of agencies, with the lacewing playing a very important role. Prominent also was parasitism, which affected 40 to 50 per cent. of the aphid population during the last week of July. The production and subsequent migration of *alatae* was no longer a factor in depleting aphid numbers, but the crop was maturing and, as a result, the rate of aphid reproduction on it was declining. Such crops, however, are able to support very high aphid populations and it was due to a great extent to the activities of *M. variegatus* that the aphid numbers were not high in this particular lucerne field.

Soon after the end of July adult *variegatus* disappeared and subsequent observations upon the population strength of the larval progeny and its effect on aphid numbers proved impossible to obtain, owing to the lucerne crop being cut.

The reason why *variegatus* was so plentiful in this field is thought to be the situation of the field in relation to trees and shelter, rather than the possibility of 1952 being a peak year in lacewing abundance.

In common with all lacewings, *M. variegatus* is a very weak flier and its disproportionately large wings make it extremely vulnerable to wind. The field at Wellesbourne was small and surrounded by trees and high hedges, whereas in previous years the lucerne fields from which data have been obtained were of a larger and much more open type. In consequence, although all fields possessed the kind of herbage favoured by *variegatus* and at the same time supported aphid colonies, the Wellesbourne field alone supplied very considerable shelter.

LABORATORY OBSERVATIONS.

In addition to the field observations, certain laboratory rearing experiments were conducted and data obtained on the development rates and the aphid consumption of larval *variegatus* at four different constant temperatures.

About twelve *variegatus* adults of both sexes were swept from the lucerne field on 24th July and were put into a cellophane cage containing a potted bean plant which supported a vigorous pea aphid colony. Several eggs were laid on the bean leaves but many were deposited on the upper part of the cage, either on the cellophane walls, or the muslin top. This upper region was the favourite resting place of the adults.

On 30th July more than 70 eggs were separated out and put individually into gelatin capsules. To avoid damage, the eggs were not removed from the cellophane upon which they had been laid, but instead the latter was cut up into small pieces, each piece supporting a single egg. The capsules were then put into a constant temperature of 45° F. This temperature delayed eclosion in all cases, and with the most freshly laid eggs up to a period of 21 days. It also had the desired effect of reducing the activity of the larvae between the time of emergence and utilisation. Mortality from exhaustion due to excessive foraging in the absence of food was thus reduced to a minimum.

The larvae were collected daily, and a total of ten, each within a separate, numbered capsule, were put in each of four constant temperature chambers. The temperatures used were 45° F., 50° F., 55° F., and 60° F. Each day the larvae were supplied with a known number of fresh pea aphids of constant size, and a small piece of bean leaflet was also added.

The larvae passed through three instars and were found to be difficult to rear, the mortality rate throughout the experiment being in the order of 50 per cent.[1] Between each moult there was an inactive period which varied in duration with the temperature. At 60° F. it lasted from one to two days but became prolonged to five days at 45° F. It was during these immobile periods that the majority of deaths occurred, and more especially during the inactivity before the second instar. On reaching such a stage, the larvae ceased to eat and remained motionless, invariably inside the curled-up piece of bean leaf, to await ecdysis. It seemed that they now either shed their skins successfully and became active again within a given time, or failed to moult and remained inactive until death ensued.

Table III gives the time taken by each larval instar of *variegatus* at four different temperatures. It shows that at any one temperature the period occupied by the respective instars was greatest in the case of first instar larvae and least in the case of the second.

TABLE III.

	Number of days per instar.			
Temperature.	1st.	2nd.	3rd.	Σ
60° F. . . .	6	4	5	15
55° F. . . .	8	5	6	19
50° F. . . .	10	7	8	25
45° F. . . .	13	10	12	35

The graph (Fig. 1) shows the curve obtained by plotting the total development times against temperature. It will be seen that development times were progressively shortened as the temperature rose but that over the range of temperatures used, the velocity curve was not quite a straight line. The maximum temperature involved, that of 60° F., is slightly lower than the average July, August and early September temperatures experienced in the field. The graph, therefore, represents the lower half of the normal development curve of *variegatus*, and as such displays the same characteristic lag phase towards the bottom that has been noted with different insects by other workers.

In making the daily assessments of aphid consumption by the larvae, a low-power binocular microscope had to be used to separate aphids which had been attacked and killed by *variegatus*, and those which had died from other causes. This was especially necessary when the body of the attacked aphid had been incompletely deflated and was consequently nearly identical with that of a dead unattacked specimen.

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[1] Killington stated that both he and Withycombe failed to rear *variegatus* larvae to maturity and he had consequently to rely on the account given by Brauer in 1871 for a description of the third instar larva. This description appeared to fit closely the third instar larvae reared in the present experiment, one of which is figured in Plate 1*b*.

The records thus obtained showed that the consumption of aphids increased progressively as the larvae grew in size, and was proportional to the speed of development. At 45° F., the mean daily consumption throughout complete larval development increased from a first day diet of 0·66 second instar pea aphids up to 8 third instar pea aphids on the last day. At 60° F. the corresponding consumption by *variegatus* larvae was 2 second instar pea aphids on the first day, rising just prior to pupation, to 16 third instar pea aphids. This shows that whilst it took the larvae more than twice as long to develop at 45° F. as it did at 60° F., i.e., 35 days and 15 days respectively, the consumption rate at 45° F. was just under half what it was at 60° F.

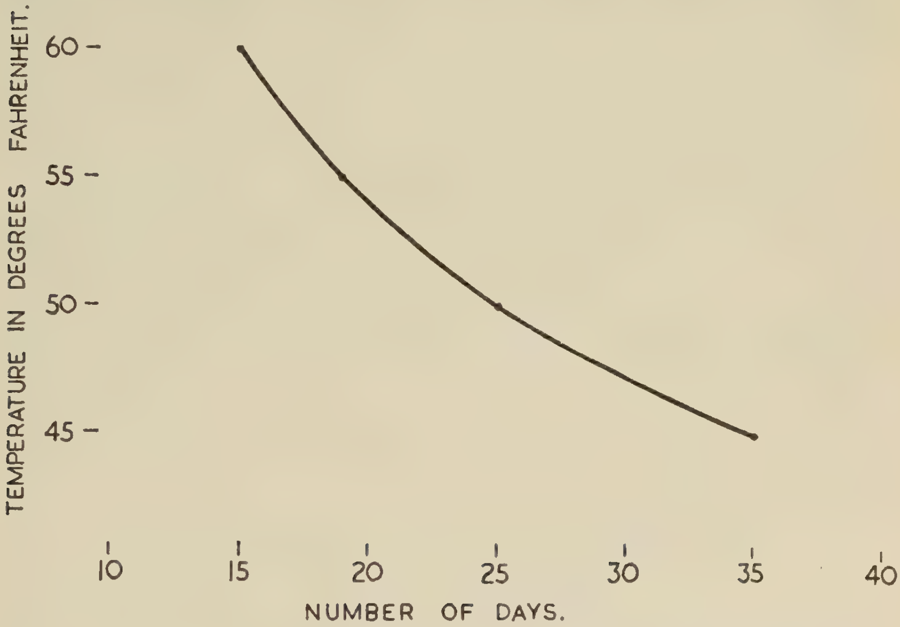

Fig. 1.—Graph showing time taken by *Micromus variegatus* larvae for complete development at temperatures between 45° F. and 60° F.

The total number of second and third instar pea aphids consumed during the larval stage averaged 70, and ranged from 54 to 82, varying with the completeness with which individual larvae consumed their prey, but not apparently with the different temperatures involved.

On reaching maturity the larvae spun loose oval cocoons and pupated in them. The cocoons were left in the same temperatures at which the respective larvae were bred. The majority of pupae failed to hatch but enough emerged at 55° F. to show that the average time taken at this temperature was 34 days. The whole life cycle can, therefore, be expected to occupy about 7–8 weeks at 60° F. This means that in the south of England, during a year of average temperatures, a warm September and an adequate food supply, three generations of *variegatus* probably occur. The females would then be on the wing ovipositing during or about May, in July or thereabouts and again from mid-September.

Discussion.

The number of generations, as well as the total aphid consumption, of *M. variegatus* show an interesting and not unfavourable comparison with the number of generations and aphid consumption of the smaller syrphids. These smaller syrphids, *Platycheirus* and *Melanostoma* species, are the most commonly found hoverflies in fields of perennial legumes, and in lucerne their larvae are regular and important predators of the pea aphid. They undergo 2–3 generations a year and the appetites of the larvae are just a little greater than that of *variegatus* larvae. Dunn (1949) gave the consumption of pea aphids by one *Platycheirus scutatus* larva as 71, this total being composed of aphid forms which were bigger on the whole than the average total of 70 second and third instar pea aphids upon which *variegatus* developed. The slightly higher aphid consumption by these syrphid larvae, however, is probably more than offset by the fact that *variegatus* adults also feed on aphids, whereas adult hoverflies are nectar feeders at flowers.

Micromus variegatus, therefore, is capable of rivalling both the aphid eating capacity of the smaller syrphid larvae, and, as seen from one sheltered lucerne field, the extent to which the latter occur. Furthermore, in fields where there is a scarcity or absence of flowering weeds and hedgerow plants, the independence of the adult lacewing of nectar as a source of food must further enhance its comparative predator value.

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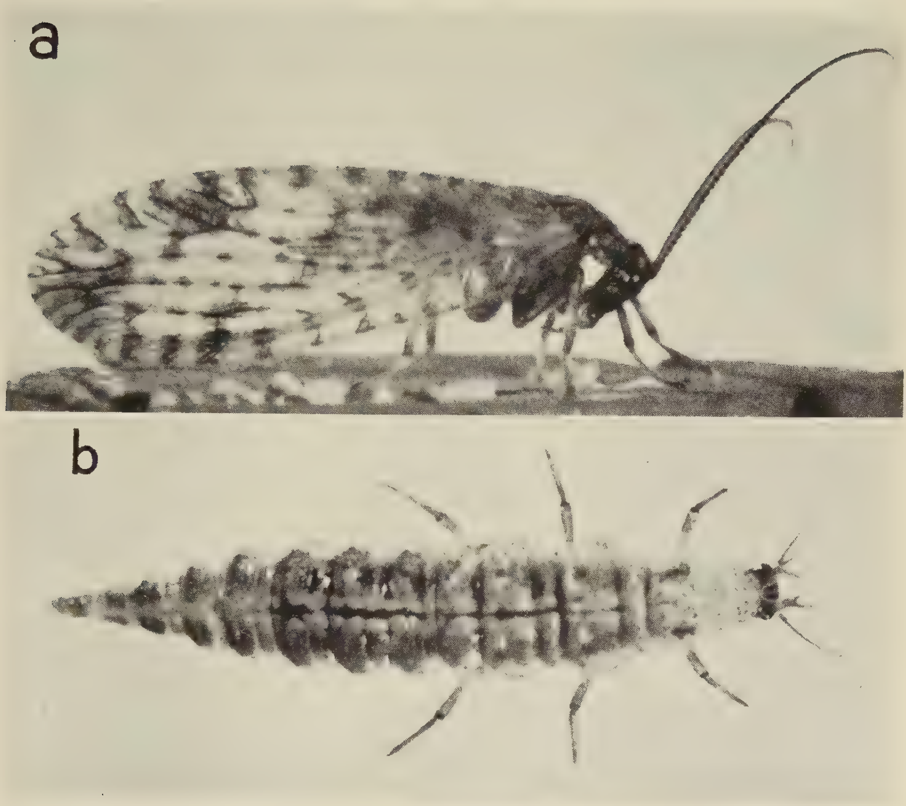
PLATE 1.—*Micromus variegatus* Fabricius. (*a*) Adult in resting position. × 12. (*b*) Third instar larva. × 16.



Micromus variegatus Fabricius.

J. A. Dunn.

Adlard & Son, Ltd., Dorking.

BIONOMICS OF SOME AFRICAN ASILIDAE.

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Introduction.

From early February, 1950, to late April, 1951, African flyboys, usually accompanied by me for the first three months, and occasionally thereafter, were engaged daily except Sundays in catching tsetse and marking flies at 75 catching-points arranged 100 yards apart along an " octagonal spiral " fly round. While so engaged they also marked and released Asilidae, each specimen receiving an individually distinctive mark. The spiral was in 4° 10′ S. latitude and 35° 42′ E. longitude ; its altitude varied from about 4000 to 4500 ft. The country is near the Eastern Rift and has a young topography with many outcrops of gneissic rock. It is deeply dissected by valleys and ravines, the hills being clothed with very open woodland of tall spreading *Brachystegia tamarindoides* Welw. ex Benth., giving way on low slopes to grassland with the small trees *Combretum zeyheri* Sond. and *Acacia* cf. *holstii* Taub., and at higher elevations to grassland of *Themeda triandra* Forsk. with such small trees as *Protea*, *Faurea* and *Piliostigma*. The valleys are mostly choked with riverine thicket topped by tall trees, and are the characteristic habitat of Sykes' monkey, *Cercopithecus mitis* Wolf.

One corner of the spiral fly round is traversed by the Daga-Iloi or Daghwailui river, which has a permanent spring higher up but here is without surface water in the dry season. In the rains the river periodically comes down in spate, and usually has at least a trickle of water. The rains last from November to May, but are light or spasmodic until January or February, when there begins a period of hot weather, broken by occasional storms, lasting until March, when the rains become more continuous. After the rains there is a cold period of three months when the mornings are overcast and temperatures often do not attain 70° F. (21° C.) until after mid-day.

Although several species of Asilidae were encountered on the spiral, the data collected are inadequate for all but two, *Promachus flavopilosus* Ric. and *Lamyra gulo* Loew. The first is a medium sized Asilid of typical form but the eyes in life are bright green. The second species appears to mimic a large wasp, the black and waisted abdomen of the wasp being represented by the black and yellow banded abdomen of the Asilid, and both species having grey and brown markings on the wings. The " mimic," however, appeared to be far commoner than the " model."

Promachus flavopilosus Ric.

This species was common from the start of the observations in February but then became scarcer through March to April, the height of the rains, in which month only four were seen, and thereafter one was caught on 25th May and another seen on 17th July. In the second season the first one was seen on 11th January, 1951. The sexes appeared to be equally numerous, and six copulating couples were caught; in two of these the female had recognisably worn wings, indicating that copulation is not confined to freshly emerged individuals.

P. flavopilosus was extremely local, and the great majority were found in the neighbourhood of the river; some, however, occurred in other ravines, and occasional individuals in the *Combretum*-open grass country; they avoided the rocky country under *Brachystegia.*

Some of those marked in the first season were recaptured. Thus of 75 marked in February, 1950, nineteen were recaptured, two of them twice; of those marked later there were no recaptures. An unexpected fact was that the insects were nearly always taken at or very near the point of release. The mean interval between marking and recapture was 4½ days, and the two longest-lived individuals were one caught at two and again at 19 days after initial release and another at 12 and again at 15 days. Both of these were females. Only two out of 24 were recaptured at points other than those at which they had been released; these had gone about 150 and 250 yards, in four days in each case. The short recapture periods probably indicate a short life, for emigration is clearly very slight; it is probable that mean life does not exceed a week.

The following prey was recorded for this species: flying ants, seven times; an Ichneumonid; Diptera, four times; a beetle; a Jassid twice; and an Acridid. One of the Diptera was *Gonioscelis xanthopogon* Speiser, another species of Asilid common in the rainy season. Sexes were not always recorded, but those with prey included one male and four females.

Lamyra gulo Loew.

Like *Promachus flavopilosus*, this large wasp-like Asilid became scarcer from February through March to April, 1950, after which three were caught in May and one on 7th August. In 1951 the first two were caught on 18th January. The sexes were caught in roughly equal numbers and there were six copulating pairs. Unlike *Promachus flavopilosus*, *Lamyra gulo* was not concentrated on the river, and it was widespread even in the rocky *Brachystegia* country. Although about 100 were marked, only five were recaptured, the distances travelled being, in hundreds of yards, 0 in 1 day, 3 in 43 days, 1 in 35 days, 1 in 2 days and 0 in 4 days; both the long-term recaptures were males. The last of these five recaptures was of particular interest because it was marked before, and recaptured after, two nights of exceptionally heavy rain; it is known that this species spends the night firmly grasping a tall grass stem, and this particular specimen, which was marked and recaptured in open *Combretum*-grass country, had evidently weathered these two severe storms without any shelter. The male recaptured after 43 days had been marked pink and green, and the pink marks (oil paints) had faded nearly white. This does not happen when tsetse flies are marked, presumably because the tsetse rest in sheltered places whereas *Lamyra gulo* rests exposed to rain and sun.

The prey of this species was mainly Aculeate Hymenoptera: an ant, five bees, a large spider-eating wasp that the captor could carry only slowly, a Bembicid wasp, a Eumenid wasp, a sawfly, a beetle, a black-and-orange Dipteron and two Asilids, one of them the slow-flying *Promachus aequalis* Loew and the other a smaller species. On one occasion *Lamyra gulo* was seen to capture another Asilid believed to be *Promachus flavopilosus*, but the prey was lost in catching. Five males and eight females were recorded as having prey. My colleague Mr. W. H. Potts has twice recorded the tsetse *Glossina morsitans* Westwood as prey of *Lamyra gulo*.

OTHER SPECIES.

Alcimus taeniopus Rond. was a large species found in rivers and ravines early in February, 1950 ; it reappeared in December and was last seen on 9th February, 1951. Five were recaptured at intervals up to a week, every one at the site of release. *Promachus aequalis* has already been mentioned ; it is fairly common in the rainy season up to early May and frequents long grass by the river ; in the second season the first one was noticed on 19th January. My senior African assistant recorded it elsewhere as capturing a male tsetse fly (*G. morsitans*). Two other species of *Promachus* near *abdominalis* Ric. were common about the end of the dry season, together with a species of *Alcimus*, and in December there appeared a few *Promachus negligens* Adams.

There was one other species of interest which it has not been possible to identify. This is a black-and-grey Asilid which is peculiar in that it always rests on trees instead of on grass or on the ground as do the others. It is very difficult to catch, so that no recaptures have been made, but one marked individual was seen on the tree (*Combretum*) on which it had been caught after being repeatedly missed there on previous occasions. Others, believed to be the same individuals, were noticed time after time on the same small trees. One was seen with a tsetse prey (*Glossina morsitans*) but not caught.

Of these miscellaneous species caught with prey, one was a male and two were females ; prey included a Satyrine butterfly, a grasshopper and a Bombyliid.

SUMMARY.

1. Asilidae were captured, painted and released in northern Tanganyika along a spiral path traversed six days a week for over a year and divided into 75 sectors by catching points 100 yards apart.

2. The two commonest Asilid species were *Promachus flavopilosus* Ric. and *Lamyro gulo* Loew, both of which appeared in the rainy season.

3. *Lamyro gulo* preyed chiefly on Aculeates but also on Diptera ; *P. flavopilosus* was less specialised.

4. Both species were remarkable in that individuals moved about very little, mostly being recaptured at the point of release. It seemed that the average life of *P. flavopilosus* might not exceed a week, but some *L. gulo* were recaptured after rather long periods.

5. *Alcimus taeniopus* Rond., a rather rarer species, also moved very little from its release points ; other common Asilidae were *Promachus aequalis* Loew in the later wet season and *P.* cf. *abdominalis* Ric. and *P. negligens* at the break of the rains. *Gonioscelis xanthopogon* Speiser, another wet season form, was preyed upon by *P. flavopilosus*, which in turn was almost certainly preyed upon by *L. gulo*.

ACKNOWLEDGMENTS.

I am indebted to Dr. B. M. Hobby of Oxford and Mr. H. Oldroyd of the British Museum (Natural History) for identification of the species.

THE MALES OF *RHOPALOSIPHUM MAIDIS* (FITCH) AND A DISCUSSION ON THE USE OF MALES IN APHID TAXONOMY.

By V. F. Eastop, F.R.E.S.

(East African Agriculture and Forestry Research Organisation.)

Rhopalosiphum maidis is economically a very important aphid in many of the tropical and sub-tropical parts of the world and has recently been recorded from England (Broadbent and Doncaster, 1949, Stroyan, 1950). Although there is a vast amount of literature about this aphid the males have never been described, Hottes and Frison (1931) saying, for instance : " The sexual forms are unknown, and the late appearance of *maidis* in Illinois is suggestive either that the corn leaf aphid has an alternate host, or that it migrates each season from the south, where it is present during the winter months." Börner, 1952, suggests that *Rhopalosiphum cooki* (Essig, 1911) may be the spring form of *Rh. maidis.*

At Muguga (Headquarters of E.A.A.F.R.O., about 7000 ft. above sea level) males of *maidis* have been found on maize and also taken in insect traps. Although oviparae have been searched for, none has been found. The males are alate and differ from the alatae viviparae only in the smaller abdomen, more numerous secondary rhinaria, a relatively longer processus terminalis, and in the presence of claspers.

Measurements of male *Rhopalosiphum maidis.*

				Length of antennal segments.				Number of secondary rhinaria on antennal segments.		
	Body length.	Siphunculi.	Cauda.	III.	IV.	V.	VI.	III.	IV.	V.
1 .	2·00	0·12	0·09	0·43	0·23	0·20	0·11+0·29	50/54	28/26	25/24
2 .	1·67	0·11	0·08	0·33	0·17	0·16	0·10+0·24	57/49	25/30	21/20
3 .	1·88	0·11	0·09	0·37	0·20	0·18	0·10+0·26	55/56	25/32	19/17
4 .	2·13	0·12	0·08	0·40	0·20	0·19	0·11+0·28	57/59	28/26	17/16
5 .	1·67	0·12	0·08	0·41	0·22	0·19	0·12+0·26	61/54	34/30	19 22

All lengths in mm.

Data for measured specimens : 1, *Zea mays*, Muguga, Kenya, 6.vii.53. 2–5 trapped, Muguga, Kenya, June–July, 1953.

The secondary rhinaria extend over the whole length of segments 3-5, and are absent from the sixth, and extend over about three quarters of the circumference of the segments, leaving only a narrow band on one side without rhinaria.

Previously only one male aphid had been recorded from East Africa, an alate male of *Myzus persicae*, the type specimen of *Macrosiphum lophospermum* Theobald, 1914, from Njoro, Kenya. In June and July (the cold season) males of *Acyrthosiphon pisum*, *Chaetosiphon* (*Pentatrichopus*) *fragaefolii* and of a

PROC. R. ENT. SOC. LOND. (A) 29. PTS. 4–6. (JUNE, 1954).

Macrosiphum (*Sitobion*) sp. near *fragariae* Walker of H. R. L. (= *avenae* Fabr. of Börner, 1952) have been found or trapped at Muguga in addition to those of *Rhopalosiphum maidis*. All the males were alate. In Western Europe the males of *Acyrthosiphon pisum* and *Ch.* (*P.*) *fragaefolii* are apterous. In America the males of both species are described as alate, which has led Hille Ris Lambers (1947) to regard the American *Acyrthosiphon* as a distinct sub-species, *destructor* Johnson, and Thomas and Jacob (1941) into doubts about the synonomy of *fragaefolii*, the latter being complicated by the fact that there are probably three American strawberry feeding members of this genus, *fragaefolii*, the other species mentioned by Thomas and Jacob, *minor* Forbes and perhaps a fourth, *porosus* Patch nec Sanderson, if the latter is not identical with *minor*. There is no reason to think that the African aphid fauna is more closely related to the American than to the European ; the East African list (Eastop, 1953) contains no species otherwise peculiar to America, and does contain a number known from Europe and Asia but not from America.

There are many instances of both apterous and alate males being described for the same species of aphid. The males of *Macrosiphoniella absinthii* from Eastern Europe are said to be alate, in England they are apterous. The evidence available at the moment suggests that alate males are more common in the centre of land masses or under continental climatic conditions and that apterous males are more frequent under maritime or less extreme conditions. The production of males in Kenya without their sexual females indicates that males may be produced under conditions of low temperature but with constant daylight length, while females are not. Davidson (1929) found, that under experimental conditions, in England, " When the colonies received only eight hours daylight daily from the fundatrix stage onwards, sexual females developed in June and in subsequent months ; males did not appear until October."

The presence or absence of wings in the male may be of great use in separating very similar species or sub-species, as in *Schizaphis agrostis* H. R. L. (alate males) and *Sch. holci* H. R. L. (apterous males), where the males are produced in the same locality. But it is obvious from the examples given previously that it is dangerous to assume a specific or sub-specific difference, purely on the presence or absence of wings in the male, when the material comes from different parts of the world. More work needs to be done, both in the recording of sexuales from different parts of the world and in experiments with the factors influencing the production of sexuales, before the form of the males can be used properly in taxonomy.

SUMMARY.

Alate males are recorded for *Rhopalosiphum maidis* and are compared with the alatae viviparae of that species. Some other alate males are also recorded from East Africa and the value to taxonomy of the presence or absence of wings in males is discussed.

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BOOK NOTICE.

Bátorliget élővilága. [Fauna and Flora of Bátorliget Nature Reserve.] By VARIOUS AUTHORS. 8vo. Budapest (Akadémiai Kiadó), 1953. Pp. 486, pls., maps, text illust.

The Bátorliget Nature Reserve comprises part of a huge marsh area of N.E. Hungary, which at the beginning of the century was entirely uninhabited, but which has since been largely drained and cultivated. After two introductory papers (with seven photographs) the flora and its ecology are treated in seven papers, to which at the end of the book an account of pollenanalytic research is added. Thirty-five papers on the fauna (p. 59–447) form the main part of the volume and include faunal lists to the following orders of insects: Thysanura, Collembola, Odonata, Coleoptera (with accounts on *Nomius pygmaeus* and *Agrilus guérini*, which are regarded as autochthonous tertiary relics), Hymenoptera, Neuroptera (only *Panorpa*), Diptera, Trichoptera (only *Anabolia nervosa* Leach), Lepidoptera and Rhynchota, most of them with a discussion of zoogeographical and ecological problems. Of 4,672 forms of animals recorded 197 are new to Hungary. The text is in Hungarian, but on p. 455–463 V. Székessy, who had a great share in the production of the work, gives a summary in German, in which the discussion of tertiary, genuine glacial, boreo-alpine, and sphagnicolous relics and of pontic, mediterranean, halophilous and silvicolous elements is of special interest. On the last 23 pages new species and variations, including some Coleoptera, Hymenoptera, Lepidoptera and Rhynchota are described.

F. v. E.

BOOK NOTICES.

The Pests of Fruits and Hops. By A. M. MASSEE. 3rd edn., revised. Large 8vo. London (Crosby Lockwood & Son, Ltd.), 1954. Pp. xvi + 325, pls. Price 25*s.*

The second edition of this work, which originally appeared in 1937, was published in 1945, and the text of this new edition has been entirely revised to take into account all the changes in insecticidal treatment and the great increase in knowledge of the pests themselves.

The pests are dealt with in order under the various fruits which they attack, and in each case notes are given to assist recognition in the field, on the life cycle of the species, and on control measures.

The volume also includes a chapter by R. P. Tew on insecticides, mainly from the chemical point of view, and on spraying machinery by Geoffrey Fletcher.

The work is well illustrated by thirty-two plates of the pests and the damage caused by them.

A scientific and a general index complete the volume.

The Insect Legion. By MALCOLM BURR. 2nd edn. 8vo. London (James Nisbet & Co., Ltd.), 1954. Pp. xvi + 336, pls. Price 21*s.*

Since the first edition of this book appeared in 1939, great advances have been made in our knowledge, and changes and additions have consequently been made throughout the text of this new edition.

The work is divided into four parts: Part 1, Insects themselves; Part 2, Insects and man; Part 3, Insects and life; Part 4, The history of Entomology.

There is probably no other entomological work in which so much factual knowledge is condensed in so small a space in such an exceptionally readable form.

The World of the Honeybee. By COLIN G. BUTLER. 8vo. London (Collins), 1954. Pp. xiv + 226, 42 pls. (2 col.). Price 21*s.*

In this work, which forms part of the *New Naturalist* series, the author has brought together all the considerable advances which have recently been made in our knowledge of the evolution of the honeybee and the origins of its complex social organization. These include the discoveries of Lindauer on the division of labour in the honeybee community, and of von Frisch on the orientation of bees and on the way in which information is conveyed about the distance and direction of food sources, and the author's own recent discovery of the existence of "queen substance."

The two coloured and forty black and white plates, which have been made from the author's own photographs, are very fine examples of close-up photography and greatly enhance the work.

BOOK NOTICES.

Atlas of the Scale Insects of North America. Volume VI. The Pseudococcidae (Part II). By G. F. FERRIS. 4to. Stanford, Calif. (University Press) and London (Oxford University Press), 1954. Pp. 279–506, text illust. Price 60*s*.

Publication of this *Atlas* was begun in 1937, and this volume concludes the study of the Pseudococcidae, which was begun in Volume V, published in 1950. Pagination is continued from Volume V, and the index for both volumes is included here.

A distinctive feature of the work is the very full illustration of each species dealt with, enlarged about sixty times.

The Odonata of Canada and Alaska. Vol. I. By EDMUND M. WALKER. 8vo. Toronto (University Press) and London (Oxford University Press), 1953. Pp. xi + 292, pls., text illust. Price $13.00.

This study is based mainly on the collection of the Royal Ontario Museum of Zoology and Palaeontology, a large part of which formerly belonged to the author, who has collected and studied Odonata for more than fifty years in every province of Canada.

Part I (General) is divided into two sections. The first deals with the external structure of the adult and full-grown nymph, and the second with life-history and habits.

Part II deals with the taxonomy and geographical distribution of the Zygoptera.

The published sources of data are listed in an extensive bibliography.

The Anisoptera are expected to be dealt with in a later volume.

Very few faunistic studies of a major group of insects have so far been made for the whole of Canada, and works of this type do much to help in the exact determination of species and in improving our knowledge of geographical distribution.

LARVAE OF THE BRITISH TRICHOPTERA.—43.

By N. E. Hickin, Ph.D., F.R.E.S.

Grammotaulius atomarius Fabricius (Limnephilidae).

Many of the low-lying fields on the north bank of the Severn estuary, which are at most only a few feet above sea level, are ringed with ditches in which *Phragmites* grows abundantly. In such ditches, at Cleeve, near Westbury-on-Severn, Glos., which were about 6 to 9 in. deep and from 1 to 2 ft. across, at the end of January, 1953, I found the larvae of *Grammotaulius atomarius* Fab. extremely common, and they were fully grown. From larvae collected at this time adults commenced to emerge from my aquarium on 6th May and continued to do so until 17th May, all emerging during the night or very early morning. I am indebted to Mr. D. E. Kimmins for the identification. It is of interest to note the colour of this insect when freshly emerged. The straw-colour is suffused with a delicate peach pink. This latter, however, is lost within an hour or two of emergence. When at rest the antennae are held pressed together. Attention also should be called to my fig. 1. The dark hair-like mark is on the hind-wings, but when the insect is at rest it shows through the rather delicate translucent wings, making it appear as though the marks were on the fore wings. Larvae of this species will live in very unfavourable conditions; indeed, they can tolerate conditions of stagnation and putrescence which would prove fatal to all the other species of caddis of which, so far, I have had experience.

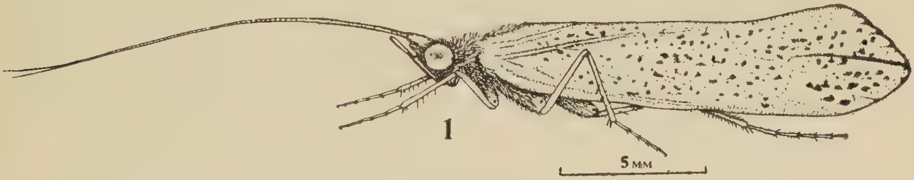


Fig. 1.—*Grammotaulius atomarius* Fabricius. Side view of adult.

Case constructed of large fragments of leaves of *Phragmites* applied longitudinally and fixed at the anterior end only, so that the posterior part of the leaf fragment is free. This gives a characteristic appearance to the case and often makes it very large, 50 mm. long and 7 mm. wide being not uncommon. The average was, however, just under 30 mm. in length and 5 mm. in width.

Larva eruciform, robust, 24 to 28 mm. in length and from 4 to 5 mm. in width.

Head: Shape as in fig. 3. Greyish-brown except three light golden-brown areas, one at apex of clypeus (which can be seen with naked eye) and a pair on the genae in the angles made by the clypeus. A white spot at the rear of each eye can be seen with 10 × lens. Small area around basal segments of antenna black whilst part of basal segment is white (easily made out with 10 × lens). Pattern of dark marks on clypeus and genae shown in

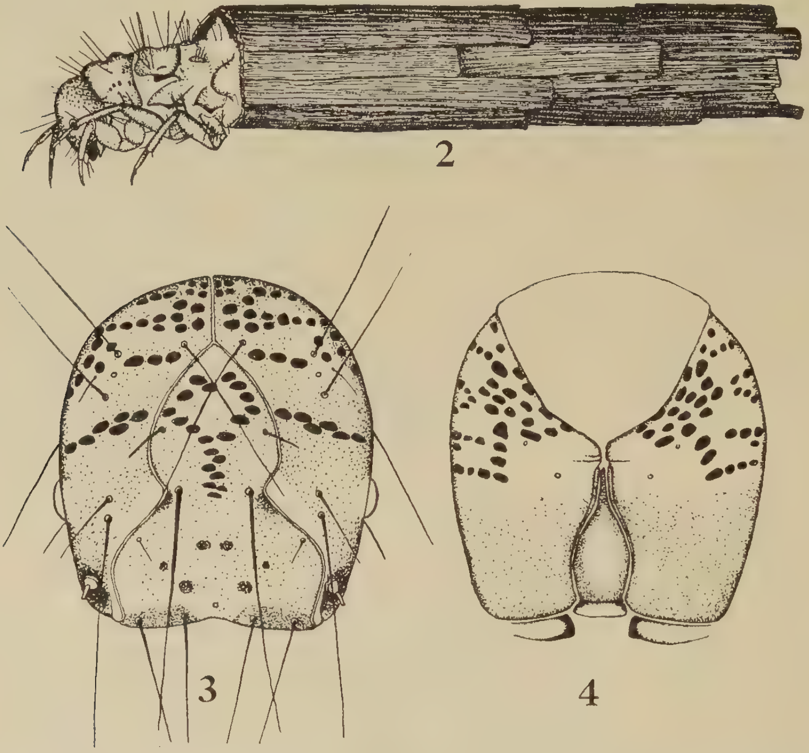
PROC. R. ENT. SOC. LOND. (A). 29. PTS. 7–9. (SEPT., 1954). 3

figs. 3 and 4, but is somewhat variable. Ventral areas of genae greyish-brown orally, shading to light golden-brown aborally. *Gular sclerite* edged with darker grey than genae but with light area in centre. Narrow folds of the genae along the gular margin.

Mouthparts do not project from head capsule.

Labrum : Anterior margin deeply incised, margin heavily sclerotised, rich chestnut in colour except for triangular area adjacent to the incision on each side, which is light yellow. The hairs around these latter areas are blunt.

Mandibles black, four teeth arranged transversely, brush of hairs on each mandible on inner edge.

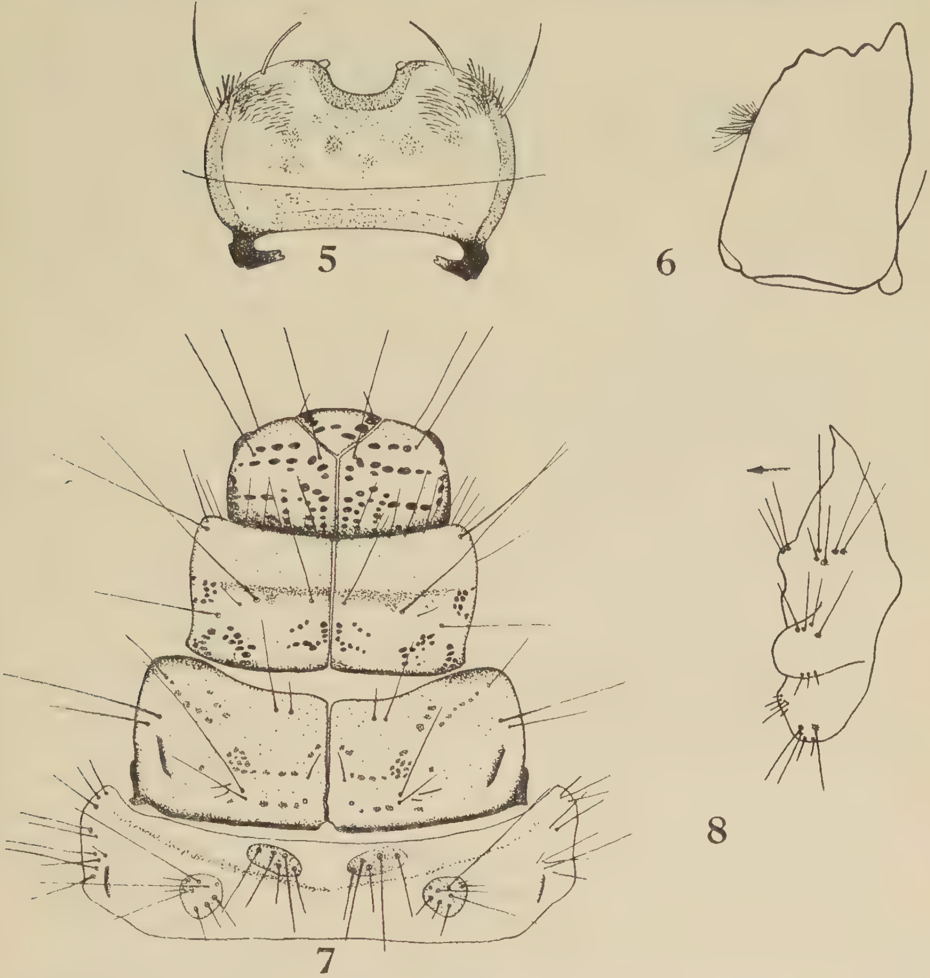


Figs. 2–4.—*Grammotaulius atomarius* Fabricius. (2) Larva in case. (3) Head of larva from in front, mouthparts omitted. (4) Head of larva from behind, mouthparts omitted.

Maxillae and *labium* short and squat. Labial palp with proximal segment bulbous with sclerotised ring around its base. Thoracic segments typically Limnephilid, marking shown in fig. 7, but fold between anterior and posterior pair of sclerites on mesonotum is yellowish or chestnut coloured. Prosternal horn yellow.

Legs also typically Limnephilid. Lestage (*in* Rousseau, 1921) gives the length of leg ratio as 10 : 14 : 15. The dark spots are well-pronounced. A good description is given by Lestage.

Abdomen : Creamy-white to greyish-white in colour. Intersegmental grooves dark grey, fairly well-defined. Protuberances on first abdominal segment well developed, dorsal protuberance conical, terminating in a sharp point directed anteriorly, at the sides of the base are thirteen black hairs of which three are at the front and five at each side. On the sternite is situated a well-defined protuberance which carries black hairs, as do the lateral protuberances (fig. 8). Lateral line present from the third to the seventh abdominal segments inclusive ; two, three or four sclerotised bifid organs present from the second to the seventh segments. Filiform abdominal gills are present on second to eighth segments and are mostly united in groups of two or three. The total number of gills is somewhat variable, but the number 84 given by Ulmer appears to be about average, and they are disposed as follows : 18 + 18 + 15 + 12 + 9 + 9 + 3.



Figs. 5–8.—*Grammotaulius atomarius* Fabricius. (5) Labrum. (6) Right mandible. (7) Head and thoracic nota from above. (8) 1st abdominal segment from the side.

Anal sclerite : Four large black bristles on posterior margin with one smaller bristle in centre, and two yet smaller bristles between the outer pairs ; a few variably situated dark marks on the anterior margin. Anal claws with one auxiliary hook and the basal lobes bearing a number of dark spots on their ventral surface. Where the sclerotised plates meet the posterior margin of the ninth segment a pair of orange coloured arrow-head-shaped marks are situated (easily visible with the naked eye).

SUMMARY.

The larva of *Grammotaulius atomarius* F. is described and figured, and a figure given of the adult.

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LARVAE OF THE BRITISH TRICHOPTERA.—44.

By N. E. Hickin, Ph.D., F.R.E.S.

Lype phaeopa Stephens (Psychomyidae).

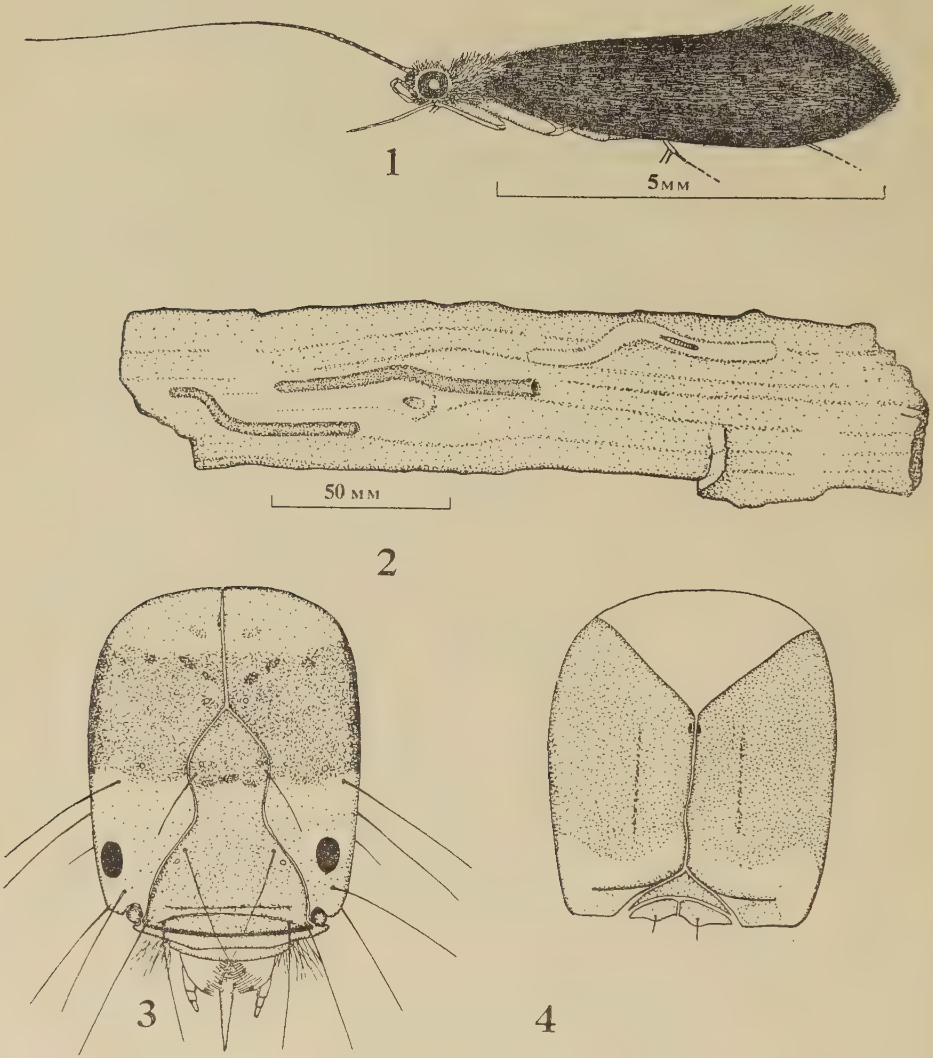
During 1953 I collected three batches of larvae of this species. On 4th April, when collecting with Mr. James Edwards in the locality of Alton, North Staffs., where the very rare Psychomyid Caddis fly *Tinodes rostocki* McLachlan is well established, we found a number of fixed galleries on branches submerged in a fast-running stream near a waterfall. From this material I was able to rear out a male adult on 6th June. The identification was confirmed by Mr. D. E. Kimmins. Like many other species of Caddis it emerged during the night or early morning. The long blackish pubescence which clothes the anterior wing has a dark brown sheen when seen from some angles. The underside of the thorax and legs are very pale straw in colour and there is a ring of this colour surrounding the eyes. On comparing these confirmed larvae with a batch of larvae found on submerged branches in a small stream at Cherrington near Stroud, Glos., when collecting with Mr. Arthur Peacey on 9th April, 1953, it was observed that they were identical. Mr. Peacey had collected adults of *Lype phaeopa* at this locality in previous years. Lastly, I have found some larvae in galleries on a submerged branch in a small trickle of water at Bletchingley, Surrey, on 24th May, 1953.

Lype phaeopa is one of the commonest of Caddis flies. It is therefore amazing that its larva has remained virtually unknown until the present time. When once its fixed galleries can be recognised, almost any stick or branch submerged in water—from the veriest trickle to a lake—will be found to contain them. The final galleries may be up to 60 to 70 mm. in length and up till the present I have found them only on submerged wood. The surface of the wood appears to be bitten out into a groove, the top of the groove being covered with a skin-like secretion to which sand grains adhere. The larva can move rapidly along its gallery and when the wood supporting the galleries is taken from the water the larvae will often leave them.

The larva of *Lype phaeopa* is almost identical with that of *Lype reducta* Hagen in my collection. My specimens of *phaeopa*, however, differ from *reducta* as follows : the dark spots on the lateral surfaces of the genae (the " cheeks ") are quite discrete in *phaeopa* but tend in *reducta* to run together with a greyish suffusion. The ventral surfaces of the genae are also much greyer in *phaeopa* than in *reducta*, although I would now like to make my drawing of these in *reducta* much darker than I actually did. In the same drawing I would now like to make the oral margin of the clypeus black, and the wide oral part grey, but not so dark as the wide, almost black, transverse band.

In *phaeopa*, also, I found that the pronotum is rather darker in colour than in *reducta*, and the white areas around the bristles are slightly larger.

Rousseau quotes Ulmer's statement that the larva of *Lype* resembles that of *Tinodes assimilis* McLachlan to an extraordinary degree. I have found that both British species of *Lype* do resemble those species of *Tinodes* which I have collected (*assimilis* McLachlan, *unicolor* Pictet, *pallidula* McLachlan) with the exception of *Tinodes waeneri*, which can be easily separated from these species with the naked eye.



Figs. 1–4.—*Lype phaeopa* Stephens. (1) Adult. (2) Three larval tunnels on piece of submerged wood, tunnel on right has had covering removed to show comparative size of larva. (3) Head of larva from the front. (4) Head of larva from behind, mouthparts omitted.

SUMMARY.

The larva of *Lype phaeopa* Stephens is described and figured, and a figure of the adult given.

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HICKIN, N. E., 1950, *Proc. R. ent. Soc. Lond.* (A) **25** : 71.
MOSELY, M. E., 1939, *The British Caddis Flies :* 223. London.
ROUSSEAU, E., 1921, *Larves et Nymphes aquatiques des Insectes d'Europe :* 524. Bruxelles.
ULMER, G., 1909, *Süsswasserfauna Deutschlands* **5–6** : 232.

Note.—It is not certain that A. J. Siltala (1905–6, *Acta Soc. Fauna Flora fenn.* **27** (6) : 138) refers to this species. *See* Rousseau (1921) : 527.

LARVAE OF THE BRITISH TRICHOPTERA.—45.

By N. E. Hickin, Ph.D., F.R.E.S.

Limnephilus centralis Curtis (Limnephilidae).

I spent 6th April, 1953, collecting with Mr. James Edwards at Chartley Moss, Staffs. We were endeavouring to find the larvae of *Neuronia clathrata* Kolenati and *Stenophylax alpestris* Kolenati in this classic locality ; we were unsuccessful in this.

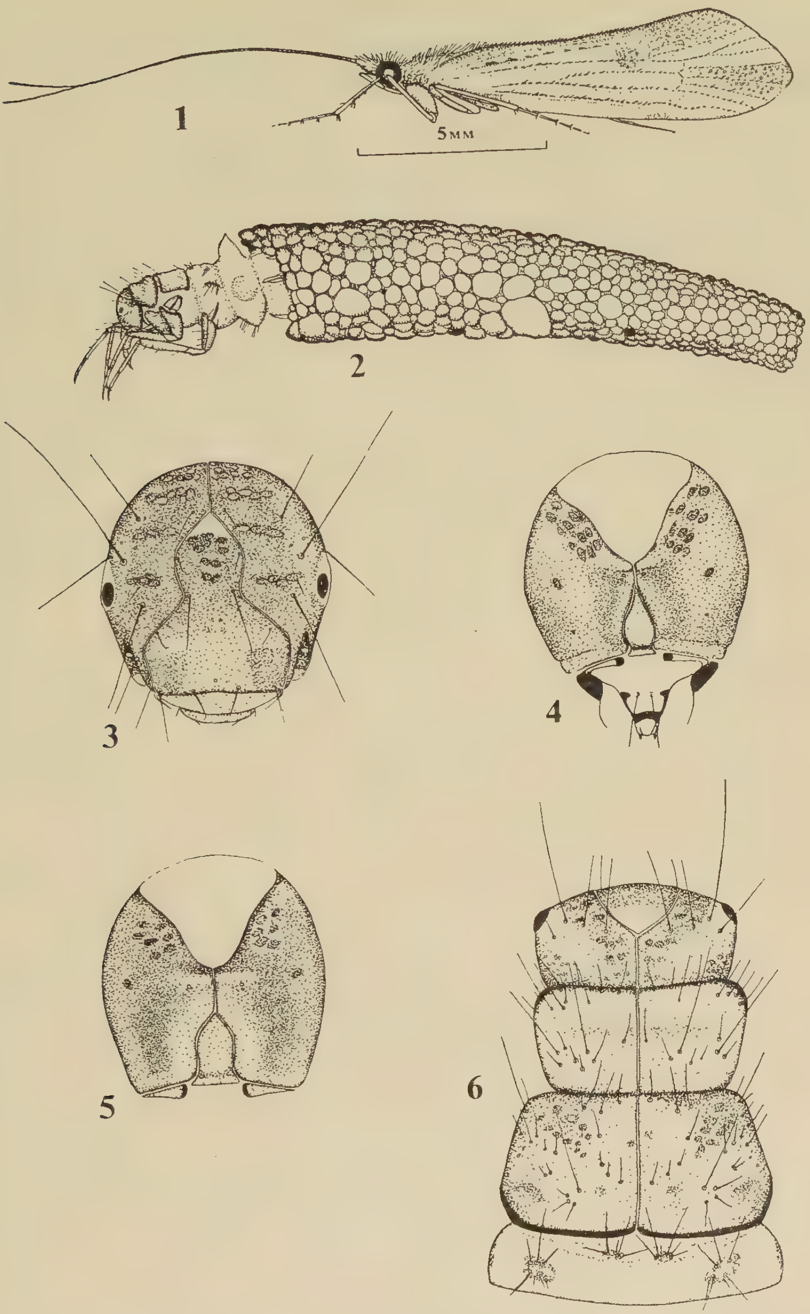
Deserting the sphagnum we netted the drainage ditches where we found larvae of *Neuronia ruficrus* Scopoli to be quite common. We then came across a small but deep ditch in which was clear running water. The ditch was almost hidden by silver birch scrub and dead bracken fronds, but larvae, afterwards found to be of *Micropterna lateralis* Stephens and *Limnephilus centralis* Curtis, in about equal numbers, were quite common. From larvae then collected a male adult of this latter species emerged on 26th May, which Mr. D. E. Kimmins identified for me. My drawing of the adult (fig. 1) was made partly from this specimen and partly from specimens in the collection of Dr. C. H. Andrewes, F.R.S., to whom I am indebted for the loan of his caddis fly collection. Ulmer gives " ditches " as the larval locality, and Mosely says of the insect that it frequents marshy localities, so that it is of interest to note that I found the larvae in a clear trickle of water in a deep ditch, although on the edge of a sphagnum bog.

The place name, Chartley Moss, no longer appears on the one inch ordnance survey map ; it can be referred to as Anglesea Coppice, Stowe, Staffs.

Case.—Of rounded sand grains, oblique opening, curved, some cases narrowing more appreciably than others and some cases slightly twisting laterally. Two cases examined. When seen from below, the hinder end twists over to the right. 13–15 mm. long, 3 mm. wide at fore end. A deep notch (as is present in the case of *Limnephilus vittatus* Fab.) on the dorsal surface of the anterior end of the case is absent but a slight one was present in a few instances.

The light colour of the sand grains stood out in striking contrast against the dead bracken and grass, on the ditch bottom when the caddis were collected.

Larva.—Generally similar to *Limnephilus vittatus* Fabricius, but it can be differentiated with ease. Length up to 12·5 mm., width 2 to 2·5 mm. *Head.*—The most conspicuous character is the absence of pigment from the triangular-shaped area at the aboral end of the clypeus. The converging longitudinal bands on the genae of *L. vittatus* (and indeed of many Limnephilids) appear in this species to be resolved into a number of transverse bands made up of darker pigmentation in the region of the muscle-spots. The pale area around the eyes is prominent. The gular sclerite is pear-shaped with a black transverse bar at the oral end. The gular sclerite of *L. vittatus* has the lateral margins parallel for some distance and the genae are contiguous on the ventral surface for a very much shorter distance than is the case in *L. vittatus* (see fig. 5). The transverse bar at the oral end of the gular sclerite is much darker in *L. centralis* than in *L. vittatus*. *Pronotum.*—Transverse groove (which is very dark in *L. vittatus*) scarcely perceptible—this is the " blackish cross " of Ulmer.



Figs. 1–6.—*Limnephilus centralis.* (1) Adult (male). (2) Larva in case from the side. (3) Head of larva from the front. (4) Head of larva from behind. (5) *Limnephilus vittatus* : Head of larva from behind. (6) *Limnephilus centralis :* Head and thoracic nota of larva from above.

SUMMARY.

The larva of *Limnephilus centralis* Fabricius is described and figured, and a figure of the adult is given.

REFERENCES.

DÖHLER, W., 1914, *S.B. Naturf. Ges. Lpz.* **41** : 39.
MOSELY, M. E., 1939, *The British Caddis Flies* : 62.
SILFVENIUS, A. J., 1906, *Acta Soc. Fauna Flora fenn.* **28** (4) : 49.
ULMER, G., 1903, *Metamorph. Trichopt.* : 54.
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NOTES ON THE BIOLOGY OF *ARHOPALUS FERUS* MULSANT (COLEOPTERA: CERAMBYCIDAE).

By H. R. Wallace, Ph.D., F.R.E.S.

(*Department of Zoology, University of Liverpool.*)[1]

In the Formby district near Liverpool there are extensive stands of Corsican Pine and Scots Pine trees. Felling during the 1939–1945 war left numerous pine stumps which now support a large population of *Arhopalus*[2] *ferus* (Mulsant). From 1950 to 1952 a study was made of the *A. ferus* population, particular attention being paid to that part of the population occurring in pine stumps.

Smith (1905) has described some aspects of the behaviour and life cycle of this beetle in unhealthy Scots pine trees in the New Forest. It is confined to conifers (Sharp, 1905). *Arhopalus ferus* is widely distributed abroad, occurring throughout Europe, Siberia, and parts of Scandinavia (Mr. E. A. J. Duffy—communication); its distribution in Britain has been worked out by Kaufmann (1948). Harris (1952) has contributed some observations on its behaviour. The present notes fill some of the gaps in our knowledge.

Life History.

The eggs are laid in batches of 1–20 under the bark of logs, dying and dead standing trees, and standing stumps of pine. The egg stage lasts 10–18 days in the field and the egg laying period extended from July to early September in the Formby district in 1951. The larvae begin to consume wood about two days after eclosion, and in stumps they usually bore downwards in the outer sapwood, following the grain of the wood. The descent of the larvae at this stage is probably a movement to higher moisture conditions and to wood with higher nutritional value. The larvae do not always continue downwards; in highly decayed stumps they may travel in a horizontal direction, avoiding those parts in the more advanced stages of decay. In slightly decayed stumps the larvae may feed on the cambium or the inner bark.

When a larva is placed in a superficial cavity cut in a piece of pine wood, and covered by glass, it is possible to observe the feeding and boring behaviour. The larva first breaks up the wood with its mandibles and packs the shreds into any space between the glass and wood. It then smooths the walls by biting off any projecting pieces of wood. The larva now starts to bore. At the "head" of the cavity, wood is broken up and ingested. Pellets of frass are produced and every two minutes or so the larva turns round and packs the pellets behind it using the maxillary palps. Eventually, a long tunnel crammed with frass at one end is formed. The frass has a smaller volume than the original wood, and so as the larva progresses through the wood the volume of the airspace in the tunnel increases. Some tunnels in stumps extend for 150 cm., of which about 50 cm. is airspace and 100 cm. is packed with frass. The vertical movements of larvae in stumps do not necessarily indicate that they are boring through the intact wood, since larvae under observation have been seen to reverse their direction and remove the frass from one end of the tunnel with their mandibles and to convey it between their palps to the other end, where it is tightly packed. Smith (1905) states that there are descending tunnels containing packed frass, and empty ascending tunnels. My observations suggest that usually only one tunnel is made and that vertical movements are carried out either by active boring or by movements of packed frass from one end of the tunnel to the other. The larvae usually bore vertically in stump boles and then when they reach the roots they continue to follow the grain. Tunnels are irregular in diameter, the larvae often consuming wood laterally. Becker (1942) states that *Hylotrupes bajulus* L. (Cerambycidae) also extends its tunnels laterally.

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[2] The generic name *Arhopalus* Serville, 1834, must replace *Criocephalus* Mulsant, 1839, as *rusticus* L. is the type species of both. (Linsley, 1940, *Ent. News* **51**: 254).

It was found that the number of larvae per stump depends on the site and size of the stump and its state of decay. The largest populations occurred in semi-decayed stumps, as many as six hundred larvae having been counted in one semi-decayed stump 25 cm. in diameter. In heavily infested wood the tunnels often coalesce.

No parasites or predators of *Arhopalus* have been observed. The nymphs of an unidentified species of mite were often observed, attached to the larvae between the segments.

Mortality is highest among larvae occurring in highly decayed stumps containing a brown rot fungus, *Tricholoma rutilans* (Schaeff.) Fr. It is suggested that high temperatures and dry conditions in the summer months, and fungal attack on the larvae, are the controlling factors. Two cases of cannibalism have been observed in the field, both in dense populations. Both of the attacked larvae were alive, although the epidermis and fat body of two segments had been eaten away on one side.

About mid-April some of the larvae in the larger size groups (approximately longer than 1 cm.) move upwards in the stump to the top of their tunnels and then bore to the outside through the intact wood. The remainder continue feeding in the lower parts of the stump. Shreds of wood issue from the mouths of the tunnels as the oval-shaped emergence holes are formed, the activity being audible several feet away. Previous work by the author suggests that the upward movement of larvae in the spring and the downward movement in the autumn is associated with the reversal of the temperature gradient in the stumps at these times (Wallace, 1953). The open end of the tunnel is sealed with shredded wood and the larva retreats from 2 to 10 cm. to its pupation site. The larva now ceases to feed and assumes a characteristic prepupal form. The body shortens and the head protrudes from the thorax. The abdomen makes a rotatory movement and locomotion ceases. The prepupal phase lasts for about a week and then pupation occurs. Several larvae have been observed to pupate without first making an emergence hole, the end of the tunnel terminating a few mm. from the surface. Smith (1905) states that the larvae pupate in a small offshoot of the main tunnel; this was not found to occur in stumps in the Formby district.

The pupa is capable of a limited amount of movement in the tunnel. The pupal stage lasts for three to four weeks, and appears to be shorter in the males. Before the final ecdysis the pupa changes in colour. The eyes become black and then there is a gradual increase in sclerotisation. The head, thorax, antennae, legs and elytra become pink and the adult is visible through the pupal skin. Ecdysis then occurs and the wings expand and harden in three to four hours. The adult makes no attempt to leave the stump. At first the adult is red, and the swollen abdomen is not covered by the elytra. The red coloration darkens as sclerotisation progresses, and on completion the female is black, the male a dark red. Females take about ten days and males six days to become completely sclerotised, but the time varies directly with size. The shrinkage of the abdomen during sclerotisation is associated with the differentiation of the gonads and the reduction of the fat-body. When the adult female has assumed its final form it remains quiescent at the pupation site for a week or more by which time it is sexually mature ; the males become active as soon as sclerotisation is completed, and they are then sexually mature. The first adults to vacate the pupation sites are the males.

The mature adults bore through the wood shreds at the tunnel mouth and emerge at the surface. They are capable of boring through solid wood ; individuals without emergence holes have, therefore, no difficulty in leaving the stump. The adults are active at dusk, when they leave the tunnels and fly away. Copulation has not been observed in the field. In the laboratory, isolated adults take to the wing at dusk also, but if males and females are placed together, at any time, copulation immediately occurs, followed by flight. A single male may during its life copulate with several females. At the commencement of copulation both sexes stridulate, the squeaking noise being due to the rubbing of the posterior edge of the pronotum against the mesoscutum. During the day fully mature adults shelter in old tunnels ; attempts to find them in other shelter sites in the pine wood area were unsuccessful.

No reference to the feeding habits of the adults has been found in the literature. No ingested material has been found in their gut, and they have never been observed to feed on flowers in the daytime. The nocturnal habits have not been studied, and it is possible that feeding occurs during this time. No wood is ingested when they leave the pupation site and make their way to the outside. The gut has a collapsed appearance in the pupa and adult, and the hind gut always contains a white granular substance which is considered to be an excretory product. In the laboratory, females copulate and oviposit without feeding. These observations suggest that *Arhopalus* resembles some other longicorns which do not feed as adults (Trägårdh, 1930).

DIAPAUSE.

During the winter, some larvae, belonging to no particular size group, enclose a small chamber in the tunnel by packing frass at either end. Within these chambers they are bent double and quite dormant. They first appear with the onset of cold weather in winter. In 1951, the first larvae in diapause were found in stumps in the clearings, in December, when the air temperature was zero on several occasions. When larvae in diapause are taken from a stump they are flaccid and show no signs of movement, but at room temperature (16° C.) they become active. Larvae dwelling at the base and in the roots of stumps are seldom in diapause ; they bore actively throughout the winter.

Diapause is not obligatory, since in the laboratory the life cycle was completed in 21 months (August 1950–April 1952) without any sign of a resting stage. Larvae reared in the laboratory at 15°–18° C. and 100 per cent. R.H. showed a

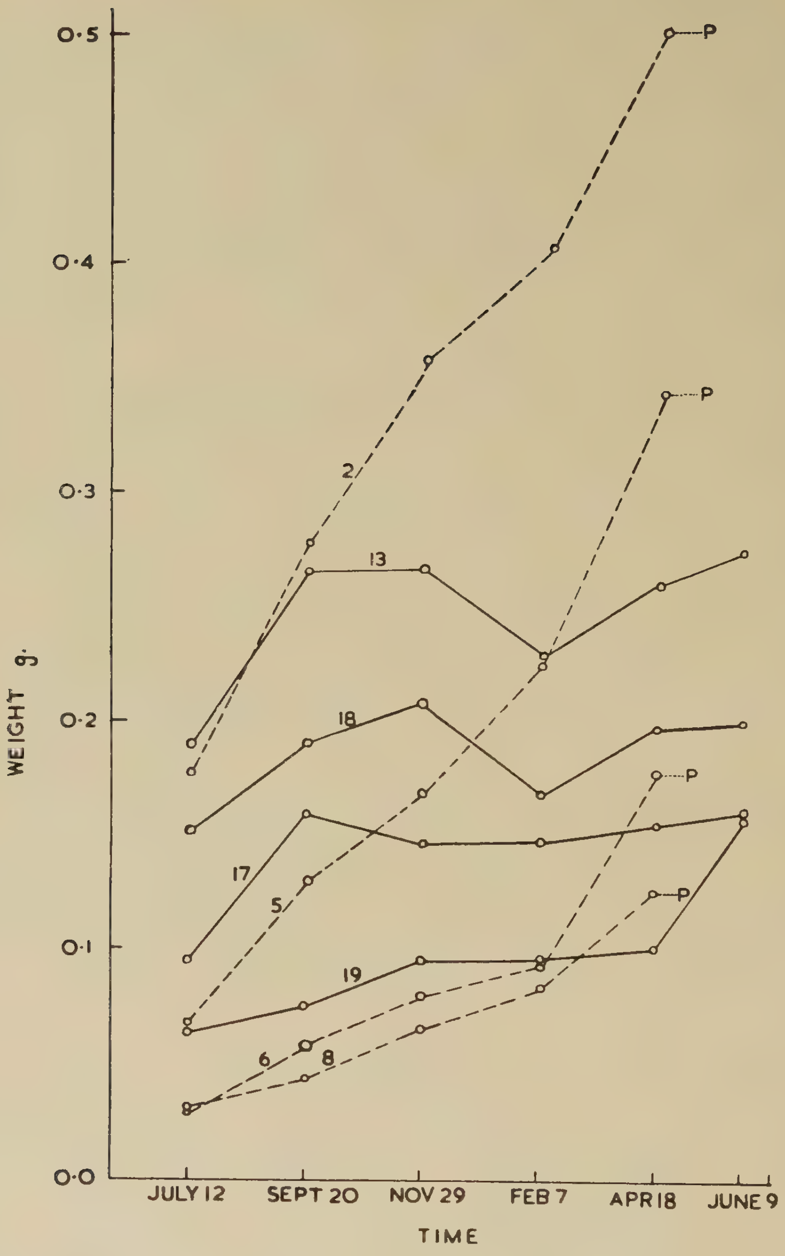

Fig. 1.—Weights of larvae of *Arhopalus ferus* from 12th July, 1951, to 9th June, 1952, at 100 per cent. relative humidity. Numerals correspond to individual larvae in Table I. P indicates that metamorphosis has occurred.

------- in laboratory, 15°–18° C.

——— in open air.

steady increase in weight until metamorphosis (fig. 1). Larvae reared in the open air in a R. H. of 100 per cent. lost weight during the winter months and formed characteristic diapause chambers. The high incidence of diapause in this experiment is attributed to the low temperatures experienced by the larvae. In the field, subsurface temperatures in stumps are higher. The relationship between larval growth and diapause was investigated as follows. In July, 1951, pine wood blocks about 20 cm. long and 4 sq. cm. in section, were cut from one slightly decayed stump, and a hole was drilled in each block for one larva. The blocks were divided into two groups and placed vertically in air-tight containers, so that they rested on a perforated zinc shelf suspended over water. After two weeks it was assumed that the air in the containers and in the cavities in the blocks was saturated. Twenty-five larvae of various sizes were then weighed and placed in the holes. One closed container was placed in the open air and the other was kept in the laboratory at 15°–18° C. Every 70 days from 12th July, 1951 to 9th June, 1952, the larvae were removed from the blocks, weighed, and then introduced into similarly treated blocks cut from the original stump. Out of the original 25 larvae, 19 survived (Table I). All the larvae which were reared in the laboratory had metamorphosed by 9th June; those reared in the open air were still larvae at the completion of the experiment.

Table I.—*Weights of individual larvae of* Arhopalus ferus *at* 70-*day intervals from* 12*th July*, 1951, *to* 9*th June*, 1952.

		Weights of larvae (g.).					
		12th July.	20th Sept.	29th Nov.	7th Feb.	18th Apr.	9th June.*
Room temperature 16°–18° C. Relative humidity 100 per cent.	1	0·158	0·259	0·295	0·309	P	—
	2	0·175	0·276	0·357	0·407	0·499	P
	3	0·104	0·138	0·154	0·179	P	—
	4	0·103	0·163	0·171	0·193	0·255	P
	5	0·067	0·128	0·166	0·221	0·340	P
	6	0·030	0·058	0·079	0·098	0·174	P
	7	0·203	0·275	0·296	0·324	P	—
	8	0·031	0·043	0·065	0·083	0·124	P
	9	0·196	0·225	0·232	0·257	P	—
Air temperature. Relative humidity 100 per cent.	10	0·177	0·245	0·256	0·250	0·239	0·256
	11	0·139	0·209	0·231	0·226	0·235	0·231
	12	0·131	0·204	0·222	0·185	0·222	0·217
	13	0·189	0·264	0·266	0·226	0·257	0·271
	14	0·143	0·224	0·248	0·228	0·246	0·257
	15	0·050	0·075	0·086	0·071	0·089	0·090
	16	0·153	0·222	0·215	0·230	0·245	0·269
	17	0·094	0·154	0·144	0·145	0·152	0·157
	18	0·151	0·189	0·206	0·167	0·198	0·201
	19	0·063	0·075	0·095	0·098	0·101	0·156

* Period from 18th April to 9th June—58 days.
P indicates that metamorphosis has occurred.

Observations in the field suggest that only a few larvae enter diapause in any one season and it seems likely that some at least will complete their life cycle without a resting stage. Temperature appears to be an important factor determining diapause in *Arhopalus* larvae. Andrewartha (1952) has described four types of insect diapause; that of *Arhopalus* most closely resembles his Type IV, in which there is a univoltine or a multivoltine life cycle, with diapause occurring in a few individuals of some generations.

TEMPERATURE AND PUPATION.

In November, 1951, larvae of various sizes, but at least 15 mm. long, were collected from highly decayed stumps in the clearings and each larva was isolated in a jar containing mechanically pulverised decayed wood. The larvae were divided into four batches which were all kept at 100 per cent. R.H. under constant temperature conditions of 20° C., 25° C., 30° C., and 35° C., in the dark. The experiment began on 10th November and the results are given in Table II. In this November sample all the larvae pupated. The graph of temperature against time is not linear (fig. 2, A). Plotting log temperature against log time gives a straight line (fig. 2, B) indicating that the relationship between time and temperature is exponential.

TABLE II.—*Time to pupation of* Arhopalus ferus *larvae at various temperatures and* 100 *per cent. relative humidity.*

Temp. ° C.	Number of larvae in the batch.	Mean time.*	Standard error of the mean time.
20	20	31·2	6·8
25	18	17·9	0·7
30	24	12·3	1·1
35	20	9·3	0·7

* The mean number of days under laboratory conditions for pupation to occur in the batch.

In 1951 and 1952 observations were made on the presence of pupae in stumps in different phases of decay and in different sites. In the clearings the first pupae were found in slightly decayed stumps at the beginning of May in both years. In stumps where the projecting parts were in a powdered condition, the first pupa was not observed until 20th May, 1951, and 22nd May, 1952. In slightly decayed stumps larvae penetrated to the cut surface in the spring and summer; in highly decayed stumps the exposed part is dry and powdered. Larvae do not occur under these conditions, they are restricted to the subterranean part. The temperature conditions at different levels in stumps have been investigated (Wallace, 1953) and the findings suggest that in May and June larvae in slightly decayed stumps probably experience higher temperatures than larvae in highly decayed stumps. If this is so, temperature may be an important factor affecting the time of pupation.

In 1951, pupae in slightly decayed stumps were present in the clearings from the beginning of May until the middle of August; in the forest they first appeared at the beginning of June and were still present at the end of September. During the pupation period—May to September—the forest stumps have lower temperature conditions than stumps in the clearings, and so it seems likely that temperature may be one of the conditions contributing to the later pupation in the forest.

In the clearings towards the end of the pupation period, in early August, 1951, larvae occurred near the cut surface of stumps. They did not pupate as was expected, but moved downwards in the stump. Smith (1905) records similar observations. When 20 of these larvae were placed in constant conditions of 30° C. and 100 per cent. R.H., the mean number of days for pupation to occur was 13·2 (standard error 0·9). There is no significant difference for the time taken to pupate at 30° C. and 100 per cent. R.H., between this August larval sample and the sample taken in November (see Table II). The relationship between vertical movements in stumps in the spring and the incidence of pupation has not been investigated but temperature conditions probably play some part. Barnes (1935), in his studies on the fluctuations in populations of gall midges, states that his observations suggest that "the larvae require a certain more or less fixed amount of temperature to develop from fully fed larvae into adults." The observations on *Arhopalus* support this hypothesis.

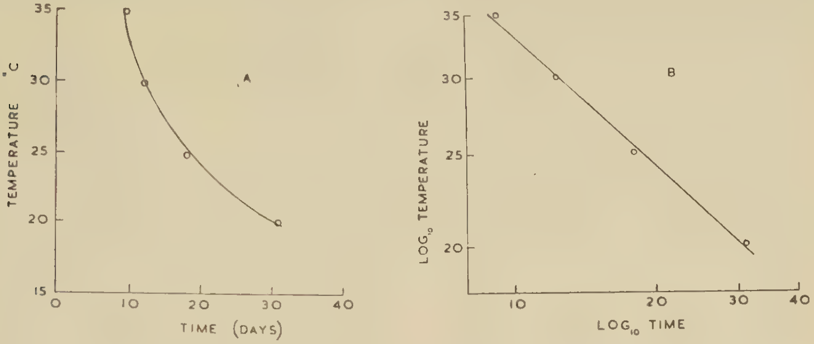

Fig. 2.—Mean number of days to pupation of *Arhopalus ferus* at various temperatures and 100 per cent. relative humidity.
A = temperature against time.
B = log temperature against log time.

Relationship Between Larval Growth and Decay of the Wood.

Becker (1942) in investigations on the physiology of the nutrition of *Hylotrupes bajulus* L. (Cerambycidae) suggests that the protein content of the wood strongly influences larval growth. He states that wood rotting fungi increase the nutritive value of the wood for the larvae to a great degree, the effect of the fungi on the wood decreasing with time.

My observations show that, whilst the larvae of *A. ferus* occur in pine wood in all phases of decay, they show a preference for wood that is only slightly decayed. In highly decayed stumps the larval population concentrates in the least decayed wood. The presence of fungi appears to be essential for the existence of the larvae—they do not occur in healthy trees.

The relationship between larval growth and wood decay was investigated as follows. Pine stumps in four stages of decay were selected in the field and classified as sound, slightly decayed, semi-decayed and highly decayed. Blocks

25 cm. × 4 cm. × 4 cm. were cut from the stumps and bored and moisture conditioned (see page 103). About 80 larvae of various sizes were collected from highly decayed stumps. Each larva was weighed, then isolated in a wood block: the blocks being placed in air-tight containers in which the relative humidity was maintained at 100 per cent. The temperature conditions varied from 16° to 18° C. The larvae were weighed after they had been in the blocks for 35 days. Four of the larvae had ecdysed during this period—the exuviae being present in the larval tunnel. These larvae were rejected since it was found that ecdysis radically affects the weight increase during 35 days. The results for the four batches of larvae are given in Table III.

TABLE III.—*Increase in weight of* Arhopalus ferus *larvae reared on wood in four phases of decay.*

Batch 1. *Sound wood.*		*Batch* 2. *Slightly decayed wood.*		*Batch* 3. *Semi-decayed wood.*		*Batch* 4. *Highly decayed wood.*	
Original weight (mg.)	Weight after 35 days.	Original weight (mg.)	Weight after 35 days.	Original weight (mg.)	Weight after 35 days.	Original weight (mg.)	Weight after 35 days.
25	25	74	85	29	31	18	19
32	29	77	91	36	41	31	31
33	33	79	95	38	41	45	46
33	31	84	104	40	48	77	85
40	37	95	110	43	49	87	92
43	40	98	107	44	48	103	107
45	38	112	134	52	61	157	157
49	41	120	146	57	63	159	166
55	47	128	169	63	77	159	159
55	54	129	156	68	71	160	162
62	58	132	165	88	97	162	162
65	57	135	166	93	110	174	185
114	107	136	169	93	107	179	181
129	127	147	172	117	124	203	211
153	145	148	173	124	154	219	236
171	155	149	189	135	148	300	298
219	209	150	182	153	170	388	394
		153	180	205	237		
		159	195				
		161	186				
		161	196				
		163	195				
		197	231				

A statistical analysis of the data in Table III was made by Mr. R. L. Plackett of the Mathematics Institute, University of Liverpool, and the results indicate that:

1. The relation between the original weight and the weight after 35 days is closely linear in each of the four batches of larvae.
2. There is a strong significant difference between the means of the weight increase of each batch of larvae, when the means are adjusted for the fact that the values of the original weights differ between batches.
3. The larvae show the greatest increase in weight on slightly decayed wood.
4. The increases in larval weight decrease as decay of the wood progresses.
5. On sound wood the larvae lose weight.

The regression lines for increase in weight against original weight (fig. 3) show that there are marked differences in the growth of larvae of *A. ferus* when they feed on wood in different stages of decay.

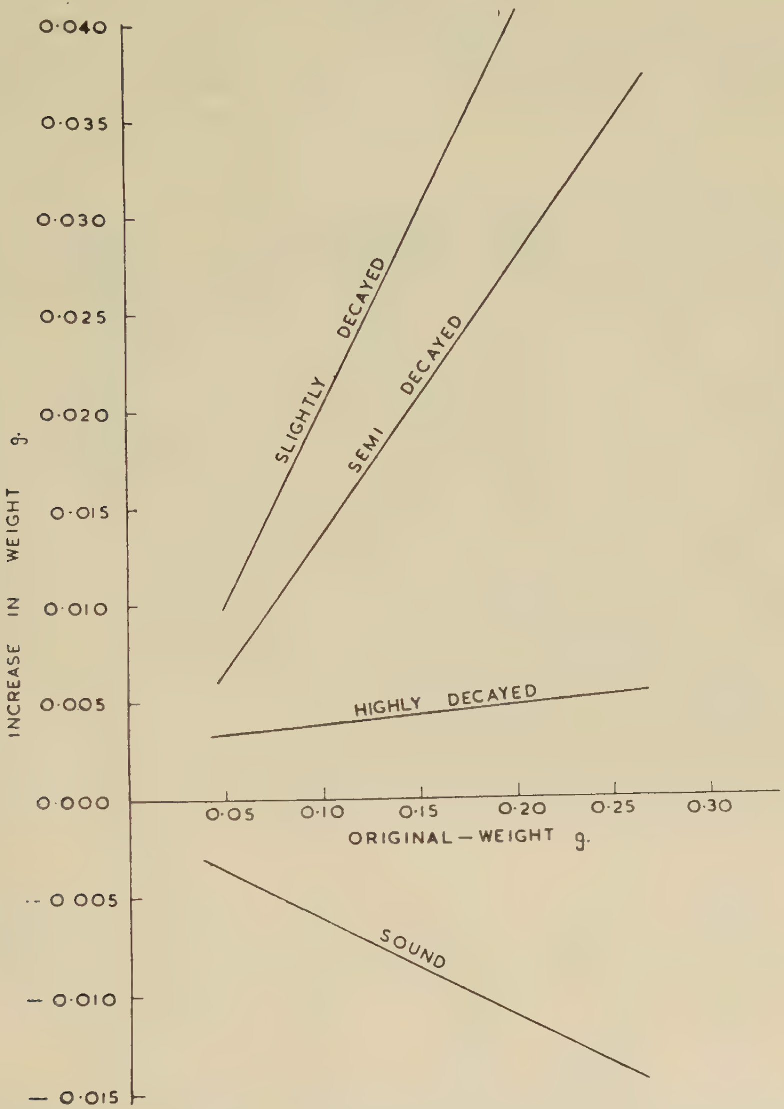

FIG. 3.—Increase in weight of larvae of *Arhopalus ferus* reared on wood in four phases of decay.

DURATION OF LARVAL LIFE.

The duration of larval life in many species of wood boring beetles is highly variable. Fisher (1935, 1940, 1941) has shown that the length of larval life in *Xestobium rufovillosum* Degeer ranges from one to ten years or more, according to conditions of temperature, moisture and fungal decay in the timber. The length of larval life of some Longicorn larvae is very prolonged, and in some circumstances may extend to 30 or 40 years (Munro 1940). In such cases a low moisture content appears to be the controlling factor. Becker (1942), by introducing proteins into timber, was able to rear *Hylotrupes bajulus* L. in one year, the length of larval life under natural conditions being about three years or more. Harris (1952) suggests that the length of larval life in *Arhopalus ferus* is approximately two years. Observations in the field on slightly decayed pine stumps showed that the emergence holes of *Arhopalus* appeared two years after the first batch of eggs were laid. Larvae reared on highly decayed wood in the laboratory had not pupated after 25 months, but when reared on slightly decayed wood, they pupated in about 21 months. Growth (expressed in terms of weight increase) and development (in terms of duration of larval life) seem to be greatest on slightly decayed wood, decreasing as wood decay increases. The evidence suggests that the length of larval life is about two years in slightly decayed stumps and probably longer in highly decayed stumps.

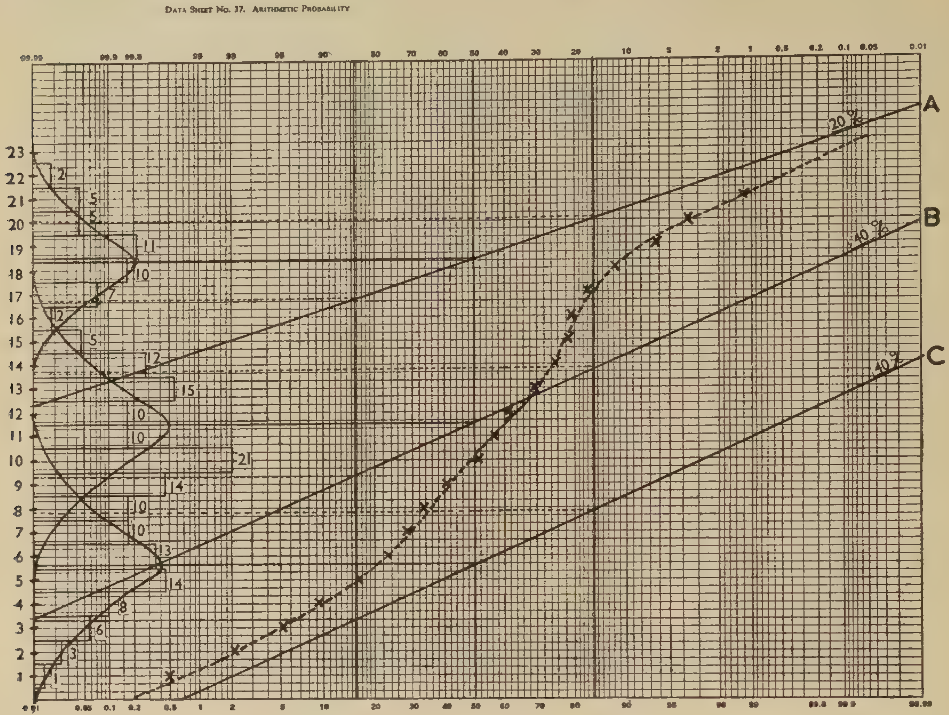

FIG. 4.—Analysis of the frequency distribution of the head capsule widths in a sample of male larvae of *A. ferus.* The histogram is on the left of the graph. Numerals 1–23 in the left margin are the class numbers. Numerals above the histogram indicate the frequencies in each class. Hypothetical distribution curves are drawn over the histogram. ×, observed data; ------, theoretical data, the resultant of the three lines A, B, C.

The number of larval or nymphal instars has been investigated for many species of insects by an analysis of the size frequency distribution. It was thought that a similar procedure might yield information on the number of larval year groups in *Arhopalus*.

Larvae were collected in a clearing from a group of 20 highly decayed stumps, all containing a brown rot. The stumps lay within an area about 20 metres in diameter. Each stump was broken up and all the larvae were collected and preserved in 70 per cent. alcohol. The whole collection was made between 2nd and 16th September, 1951, when pupation in the clearings had ceased. It was assumed that larvae of all possible ages were represented in the sample. Larvae, which had hatched from eggs laid in the field in July and August, 1951, formed a well defined group distinguishable by their small size. These larvae, assumed to be of both sexes, were excluded from the analysis. All the rest of the larvae were dissected to determine their sex, and the widths of their head capsules were measured. The larval testes and ovaries are embedded in fat-body. The male larvae are easily distinguishable under the dissecting microscope since the testes are quite prominent. There are two testicular follicles on each side of the body cavity, containing developing spermatogonia. The ovaries are difficult to distinguish in the larvae, little differentiation having taken place. They are thread-like diffuse bodies embedded in the fat-body. The head capsule measurements of the 414 larvae were analysed according to the method of Harding (1949)—males and females separately. The larval head capsule widths are arranged into classes and the frequencies are calculated for the males and females (Table IV). Histograms are constructed to show

TABLE IV.—*Frequency distribution of the head capsule width in male and female larvae of* Arhopalus ferus.

Males. *Head capsule width.*			*Females.* *Head capsule width.*		
Class No.	Class.*	Frequencies.	Class No.	Class.*	Frequencies.
1	3·4–3·6	1	1	4·7–4·9	2
2	3·7–3·9	3	2	5·0–5·2	2
3	4·0–4·2	6	3	5·3–5·5	3
4	4·3–4·5	8	4	5·6–5·8	4
5	4·6–4·8	14	5	5·9–6·1	6
6	4·9–5·1	13	6	6·2–6·4	10
7	5·2–5·4	10	7	6·5–6·7	6
8	5·5–5·7	10	8	6·8–7·0	9
9	5·8–6·0	14	9	7·1–7·3	11
10	6·1–6·3	21	10	7·4–7·6	12
11	6·4–6·6	10	11	7·7–7·9	14
12	6·7–6·9	10	12	8·0–8·2	13
13	7·0–7·2	15	13	8·3–8·5	14
14	7·3–7·5	12	14	8·6–8·8	12
15	7·6–7·8	5	15	8·9–9·1	23
16	7·9–8·1	2	16	9·2–9·4	11
17	8·2–8·4	7	17	9·5–9·7	14
18	8·5–8·7	10	18	9·8–10·0	21
19	8·8–9·0	11	19	10·1–10·3	14
20	9·1–9·3	5	20	10·4–10·6	4
21	9·4–9·6	5	21	10·7–10·9	9
22	9·7–9·9	2	22	11·0–11·2	1
			23	11·3–11·5	3

* Arbitrary units. 1 unit = 0·56 mm.

size frequency distribution and the data are plotted on arithmetic probability paper as accumulative percentage frequencies (males fig. 4; females fig. 5). When all the points are plotted in this way they form a sigmoidal curve. It is now a case of finding straight lines whose resultant most closely fits the observed data. It is then possible to estimate the modality of the population from which the samples were drawn, and for each size group to state the percentage of the population, the mean value of the head capsule width and its standard deviation (Table V). The group containing newly hatched larvae is excluded from the analysis.

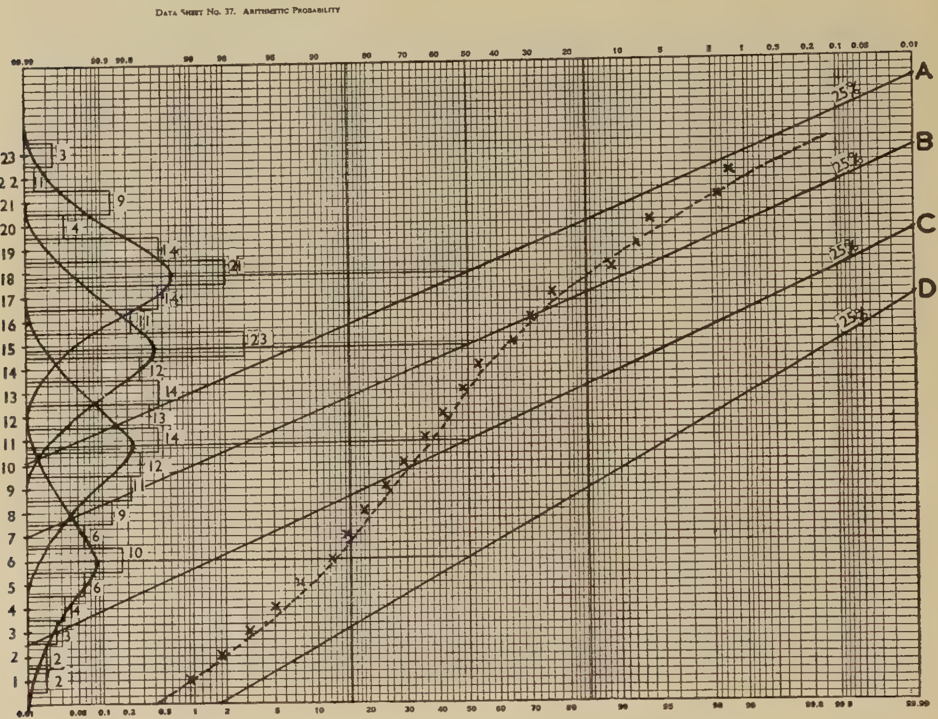

FIG. 5.—Analysis of the frequency distribution of the head capsule widths in a sample of female larvae of *A. ferus*. For explanation of the graph see legend to fig. 4.

The analysis indicates that there are probably four size groups in the males and five in the females, including the newly hatched larvae, which form the smallest size group. Each size group is considered to represent a year group. The χ^2 test for goodness of fit applied to the calculated frequencies shows that the analyses in figs. 4 and 5 are consistent with the data.

A sample of 135 adults collected from a forest clearing during one week consisted of 65 males and 70 females. The body length was measured from a point midway between the bases of the antennae to the tip of the elytra. The graphical analysis of the data, according to Harding's method indicates a bimodal distribution in both sexes (Table VI). The χ^2 test for goodness of fit showed that the results of the analysis are very unlikely to be true for the females ; for the males the analysis is consistent with the data. A bimodal distribution would be expected in both sexes if there were a variable length of life history, a longer feeding time giving larger larvae, and larger larvae giving larger adults.

Table V.—*Size groups in male and female larvae of* Arhopalus ferus.

	Size groups.						
	Males.			Females.			
	A.	B.	C.	A.	B.	C.	D.
Percentage of population	20	40	40	25	25	25	25
Mean width of head capsule*	8·7	6·6	4·8	9·9	9·0	7·8	6·3
Standard deviation	0·5	0·7	0·7	0·6	0·7	0·7	0·8
χ^2	14·05			11·03			
Degrees of freedom	13			8			
p	0·4			0·2			
Number in the sample	194			220			

* Arbitrary units ; 1 unit = 0·56 mm.

Table VI.—*Size groups in male and female adults of* Arhopalus ferus.

	Size groups.			
	Males.		Females.	
	A.	B.	A.	B.
Percentage of population	50	50	95	5
Mean body length (mm.)	17·0	13·4	19·5	11·9
Standard deviation	1·2	2·1	2·8	2·0
χ^2	6·3		20·2	
Degrees of freedom	8		10	
p	0·7		0·03	
Number in the sample	65		70	

The statistical analysis of the data for larval head capsule widths and for adult body-lengths does not contradict the hypothesis that the length of larval life is variable and lasts for at least two years, possibly extending to five or more years in highly decayed stumps.

The Economic Aspect.

The pine stands in the Formby area were originally planted to counteract the effects of sand erosion. Many of the trees on the seaward side of the stands are in a dead or dying condition—presumably due to exposure. In addition, the weevil *Hylobius abietis* L. has caused severe damage to young pine plantations. Wood-rotting fungi soon attack the weakened trees. A survey of the pine stands confirmed the opinion that *Arhopalus ferus* only attacks trees which are unhealthy ; pine stumps are the favourite habitat.

Felling of unhealthy trees during 1951 afforded an opportunity for assessing the damage done to timber by *A. ferus* larvae. It was apparent that timber which was of some commercial value was rendered unsuitable in many cases by the extensive boring through the sapwood and heartwood. In a recent paper Harris (1952) has described how imported French Maritime Pine was extensively damaged by larvae of *A. ferus*. In this case it appears that the timber was previously weakened by fire.

Arhopalus ferus greatly accelerates the destruction of pine stumps and other forest litter and, in this respect, it can be considered beneficial.

SUMMARY.

1. Observations on the behaviour and on the life history of *Arhopalus ferus* are described.

2. The relationship between larval growth (in terms of weight increase) and diapause is discussed.

3. The relationship between temperature and the time for pupation to occur is exponential. Observations suggest that temperature probably plays an important part in determining time of pupation in the field.

4. Experiments and field observations suggest that larvae show the greatest weight increase in slightly decayed wood; the weight increment decreases as wood decay progresses. On sound wood the larvae lose weight.

5. Field studies combined with a graphical analysis of the frequency distributions of larval head capsule widths and adult body-lengths, support the hypothesis that the length of larval life varies from two years in slightly decayed stumps to five years in highly decayed stumps.

6. *A. ferus* may cause extensive damage to unhealthy trees and destroy timber of possible commercial value. The larvae greatly accelerate the destruction of pine stumps and other forest litter.

ACKNOWLEDGMENTS.

My thanks are offered to Miss M. G. C. Fordham, Mr. E. A. J. Duffy, and Dr. R. C. Fisher for much useful advice. I am also indebted to Dr. J. P. Harding who criticised my graphical analysis of the larval and adult samples, and to Mr. R. L. Plackett who analysed the results of the experiment on the growth of larvae in wood in various phases of decay.

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DIAPAUSE IN *DROSOPHILA* (DIPTERA : DROSOPHILIDAE).

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During a study of Scottish species of Drosophilidae (Basden, 1952, 1954), it was discovered that larvae of *Drosophila deflexa* Duda went into diapause from autumn until spring, whether they were kept in an unheated outdoor insectary or at a constant temperature of 18° C. The following observations on larval diapause were incidental to routine note-taking on progress of stocks, and were not a definite study of diapause.

Stocks of *D. deflexa* are maintained in 7 lb. glass jars (7¾ in. high × 6 in. diam.) containing a piece of tissue paper (resthold), a small dish of water-soaked cottonwool (drink), and a small larval food pot (2 in. diam. × 1¼ in. deep) of unmixed equal quantities of fermenting apple and *Drosophila* medium (maize meal, molasses, agar, yeast and water boiled together). Each food pot will maintain several hundred larvae. Usually 70 adults are added, and the muslin top is brushed with a little benzyl benzoate solution (5 per cent. in 95 per cent. alcohol) as a mite preventive. A new food pot is added to the Parent Jar each week and is marked with that date, and the older food is transferred to a Stock Jar, which subsequently supplies adults for the next generation parent jar. The normal minimum egg to adult life-cycle at 18° C. varies from 30 to 40 days. No culture has been kept at a temperature higher than 18° C.

Most information on the diapause has been obtained from Stock 310, started 5.vii.51 from 1 ♂ 1 ♀ *D. deflexa* trapped at fermenting apple 4.vii.51 at Dalkeith Park, Midlothian. They were placed in the F1 parent jar in an unheated outdoor insectary, and transferred to 18° C. on 31.vii.51, when the female was dead. 13 ♂ 17 ♀ F1 flies emerged 27.viii–1.ix.51 and were added to the F2 parent jar at 18° C. The presence of any larvae in the F1 food pot was not noted.

The subsequent development of cultures is conveniently shown in Table I.

The F2 stock jar 1 was partly submerged in a small box of dry sawdust in the insectary, and dry cottonwool was placed on top of each pot to facilitate observations upon the development of the larvae, which tended to congregate beneath it. During the period in the insectary the temperature fell to or below freezing many times from 8.xii.51 to 1.iv.52, the coldest continuous spell lasting from 16.i to 5.ii.52, when it froze every day (min. 20° F. (— 6·7° C.), max. 37° F. (2·8° C.)). After 29.ii the minimum temperature did not drop to or below freezing point, except for 2 days in mid-March and 2 days at the end of March, and thereafter it remained above 40° F. (4·4° C.), but did not reach 50° F. (10·0 C.) until 13.v.52. The maximum temperature did not rise to 50° F. until late February, 1952, except for a few days mid-December, 1951 ; to 60° F. (15·6° C.) mid-April ; and to 70° F. (21·1° C.) mid-May, except for 2 days of 71° F. mid-April. The temperature within the period when the larvae began to pupate (12–26.v.52) was min. 50°–57° F. with 46° F. once ; max. 63°–76° F., once 59° F.

It will be seen from the table that the later pots (i.e., later layings) of the F2 generation (those in stock jar 2) produced early adults, whereas the earlier pots (stock jar 1) did not do so. A tendency for more early adults to appear from later pots than from earlier ones was noticed in some subsequent generations, but notes were not kept.

When it was discovered on 26.v.52 that the larvae in F2 stock jar 1 in the insectary were pupating, adults that emerged at 18° C. on or after that date

TABLE I.—*Development of Cultures.*

Generation (date started).	Temperature.	Number and dates of food pots.	Development.
F2 (27.viii.51) Stock Jar 1	18° C. To unheated insectary 8.xii.51	5, 27.viii–24.ix.51	*8.xii.51.* Plenty of larvae (some dead); no puparia. *21.iii.52.* Plenty of live larvae that appear ready to pupate. *12.v.52.* No puparia. *26.v.52.* Many puparia in all pots. *2.vi.52.* No adults. *4.vi.52.* 4 F2 adults out. *2–28.vi.52.* 220 F2 adults emerged, with more later.
F2 (27.viii.51) Stock Jar 2.	18° C.	5, 2–30.x.51	*26.xi.51.* Puparia in pot 30.x at least. *26.xi–3.xii.51.* First F2 adults (5♀) out. *26.xi.51–22.iv.52.* Total of 111 F2 adults emerged in 1's and 2's ; larvae still present.
F2 (27.viii.51) Stock Jar 3	18° C.	4, 5–26.xi.51	Not noted.
F8 (22.ix.52) Stock Jar 1	18° C.	5, 22.ix–21.x.52	*24.xi.52.* Swarms of large larvae, very few puparia. *10.xi.52–6.i.53.* 408 F8 adults emerged, plus more later.
F9 (17.xi.52)	18° C.	1, 24.xi.52	*29.i.53.* Food pot isolated from Stock jar, in which F9 adults are emerging. *29.i–7.iii.53.* Total 11 (? more) F9 adults emerged, in ones and twos. *7.iii.53.* Immature stages present : Live larvae 520 Dead ,, 52 (most outside of pot) Prepupae 44 Puparia (empty and full) 334 950 insects.
F11 (14.iii.53)	18° C.	6, 14.iii–c. 20.iv.53	*21.iv–27.vi.53.* 2861 F11 adults emerged.

were not used for culturing. In this way it was hoped to build up a non-diapausing strain, as was done with the Basden strain of the moth *Ephestia elutella* Hbn. (Waloff, 1948, 1949; Andrewartha, 1952 : 72, 98). Actually only progeny of *D. deflexa* adults that emerged up to 5.v.52 were used to continue the stock. It is possible that some adults were from larvae with a prolonged life, for when food pots of different dates were kept in one stock jar the emergence from individual pots could not be followed.

The larger numbers of flies that emerged from F8 stock jar 1 indicated that a smaller proportion of larvae was diapausing the second winter. More precise details were obtained from a pot of the F9 generation (see Table I). Of the total of 898 insects (excluding the dead larvae) in the pot, 57·9 per cent. were still in the larval stage and presumably in diapause, and 42·1 per cent. had pupated or were about to do so.

As observed from the F2 and F8 generations, the larvae of *D. deflexa*, at 18° C., enter diapause during the month of September or before, but a proportion will develop normally to adults. This proportion increased greatly the second winter, but some larvae still remained in diapause up to March or April. After April, 1953, it was apparent, from the emergence of large numbers of flies, that diapause was not very evident. It is likely that larvae in nature are ready to pupate in March, but do not do so until the temperature remains somewhere above 50° F. (10° C.), as noted for F2 stock jar 1. During the summer months of 1952 and 1953 the stocks (F6, F7, F12) yielded large numbers of adults without trouble. No cultures were kept in the unheated insectary during the second winter. The increase in the proportion that developed without diapause during the second year was no doubt due to breeding from adults that, as far as was known, were from non-diapausing larvae.

A larval diapause in the genus has been indicated for *D. guyénoti* Burla, (Burla, 1951 : 75), but the true identity of this species is not clear, two species (*D. deflexa* and "*D. guyénoti*") possibly having been confused and combined in the original material (Basden, 1954). The prolonged larval period, as mentioned by Alpatov (1929 : 419–420) for *D. melanogaster* Mg., where second-stage larvae at 28° C. remain as larvae for up to 72·5 hours instead of the usual 50 hours or less, is not here considered as a diapause because of lack of precise information.

A reproductive diapause occurred in the adult of *D. nitens* (Buzzati-Traverso, 1943 : 6) at 25° C. from November to March. A few of the females reproduced the first year but a considerably higher proportion did so the third year, though more slowly than normal. This diapause could be broken by exposing the adults for 10 days to temperatures of 2°–5° C. one month from (sic) the beginning of the diapause and returning the flies to 25° C. (Bertani, 1947). Herting (1953) considers *D. nitens* to be the same species as *D. rufifrons* Loew, which is closely allied systematically to *D. deflexa*. Thus the two morphologically similar species diapause in two different stages. Burla (*op. cit.*, 71) gives the larva of *D. nitens* as the diapausing stage, when doubtless the adult is meant.

A reproductive arrest is known in wild females of the American *D. robusta* Sturtevant during September to December (Carson and Stalker, 1948; Levitan, 1951 : 287). The females of autumn populations consist principally of non-breeding virgins with undeveloped ovaries, and with unusual heavy sheets of fat in the abdomens. These females, however, when mated with contemporaneously caught males reproduced in the laboratory (at ? 25·5° C.) after a mean period of, apparently, 10 days. With old-established stocks of *D. robusta* in the laboratory there is no interruption or delay of breeding.

This Carson-Stalker arrest will probably be found in other *Drosophila* species in temperate (cold-winter) regions, as indicated by my own observations. Female *D. subobscura* Coll. were trapped in woods in the Edinburgh district xi.51, ii.52 and iii.52 and were dissected. The ovaries, including the short stalk (calyx), were measured by comparing their length with that of the hind tarsus (excluding claws), which lies conveniently near during dissection. An ovary packed with fully developed eggs is 1½–2 times as long as the five tarsal segments together.

Of 60 females trapped 6–16.xi, 56 had very small immature ovaries less than half the length of the hind tarsus ; 2 had ovaries equal in length to the last 4 tarsal joints (i.e., a little more than half the length of whole tarsus, as 9 : 7) ; 1 had fully developed ovaries ; and 1 had a very small ovary of a baggy, collapsed appearance. Fifty-nine of these flies were examined for sperm but none had been inseminated.

Seventy-six females were trapped 22.ii–29.ii, of which 75 had very small immature ovaries and 1 contained one fully developed egg but no obvious ovaries. None was examined for sperm.

Thirty-eight females trapped 29.ii–7.iii had very small ovaries, none being larger than the last 4 tarsal segments. Two of the 35 examined for sperm had been inseminated.

Seven females trapped 21.iii–28.iii were recorded as having " immature " ovaries and 8 others had ovaries containing fully developed eggs. No sperm, however, was found.

In addition to dissections, females trapped in woods near Edinburgh in the autumn were isolated in vials of *Drosophila* medium, in which the species breed quite well, and were kept at 18° C. Four *D. obscura* Fall. and 1 *D. tristis* Fall. trapped between 24.x.50 and 7.xi.50, as well as 26 *D. obscura*, 7 *D. tristis*, and 1 *D. subobscura* trapped 14.x.50 were kept in this way until 2.xii.50, but no signs of larvae had appeared in any of the vials by this date. However, from 48 ♂ ♀ *D. subobscura* trapped 17–19.i.51, immediately after a sharp cold spell (min. temp. — 4° C.), and kept together with *Drosophila* medium at 18° C., abundant adult progeny were produced by 20.ii.51. Established stocks of these species in the laboratory (constant 18° C.) breed continuously throughout the year.

The above results suggest that in woods in the Edinburgh district the ovaries of the majority of female *D. subobscura* remain undeveloped from about November until the middle of March, with insemination probably taking place around the latter time, and that overwintering adults of *D. subobscura*, *D. obscura* and *D. tristis* are incapable of reproduction in nature during this period of low temperature. It is not known, however, whether females mated the previous year could carry live sperm until the spring, which might account for the 2 inseminated females caught 29.ii–7.iii. It is hoped to continue the study of overwintering in greater detail when time permits.

The results of these observations on overwintering *Drosophila* are similar to those on the hibernating adults of the Cluster Fly, *Pollenia rudis* (Fabr.) (Dipt., Calliphoridae), in Illinois (DeCoursey, 1927). Here the hibernating flies form the most abundant generation, probably the fourth, of the year, which appears in early October and dies off by mid-April. Sperm was not found in spermathecae of females until after copulation in February, and the ovaries of hibernating females remained undeveloped (dormant) until the warm days of February and March. Also the abdomens of both sexes were usually filled with fat. The flies could be kept active during winter in the laboratory but breeding from them was apparently not attempted, so it is not known whether there was a reproductive diapause, as in *Drosophila nitens*, or only a reproductive arrest, as in *D. robusta*. It may well be that overwintering females of many species of Diptera normally remain non-inseminated and with undeveloped ovaries.

Summary.

1. The larvae of *Drosophila deflexa* Duda remain in diapause during the winter and pupate in the spring, the time of pupation probably coinciding with a period when the minimum temperature is 10° C. (50° F.) or above. In laboratory cultures at 18° C. (= 64·4° F.) a small proportion of larvae did not enter diapause and this proportion has been increased by selection.

2. Published information on diapause and reproductive arrest in *Drosophila* is reviewed.

3. Females of *Drosophila subobscura*, and probably of *D. obscura* and *D. tristis*, pass the winter in the Edinburgh district in a state of reproductive arrest, being not inseminated and having immature ovaries, but are capable of immediate reproduction when kept with their males at 18° C.

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THE FILTRATION OF PARTICLES BY THE PROVENTRICULI OF VARIOUS ACULEATE HYMENOPTERA.

By L. Bailey,

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Introduction.

The action of the proventriculus of the honeybee has been described (Bailey, 1952). It was shown that the filtration of pollen and smaller particles from the honey bee stomach was a highly efficient process and the significance of this activity was briefly discussed.

A comparative study has now been made of the action of the proventriculi of various Hymenoptera and the results of this work, although by no means a complete survey, are sufficient to indicate the remarkable superiority of this organ in the honeybee as a filtering unit and serve to emphasize its significance to the honey bee community.

Material and Methods.

The following insects were used : *Prosopis pectoralis*, *Vespa vulgaris*, *Bombus hortorum*, *Bombus sylvarum* and *Apis mellifera*. Each was fed individually with a suspension of pollen grains, stained with gentian violet, in sucrose syrup, a definite volume being delivered to the mouthparts from a capillary pipette. The insects were starved for a reasonable period (usually a few hours) before feeding to avoid dilution of the pollen suspension as far as possible by any food remaining in the crop. All insects except *Prosopis* received 0·02 ml. of pollen suspension containing about 1,440,000 grains per ml. The *Prosopis* individuals were starved for six hours before feeding but no insect would take more than 0·01 ml.

After feeding, the insects were enclosed individually in small ventilated specimen tubes, and were kept in an incubator at 30° C. for periods of time ranging from a few seconds to a few hours. After these periods the insects were decapitated and the alimentary canals were withdrawn from their bodies by pulling away the terminal abdominal segments. The crops were burst on a haemocytometer and the concentration of the pollen grains in the contents was estimated.

Results.

These are given in fig. 1. It is clear that there is no significant filtration of particles from the crop by *Vespa* or by *Prosopis*. The first three *Prosopis* individuals had not been completely starved and had unstained pollen in their crops in concentrations of 1,160,000, 2,400,000 and 1,920,000 grains per ml. respectively. The stained pollen suspension with which they were fed had therefore been diluted to some unknown degree and this can account for the concentration of the stained pollen being somewhat low in these three individuals. The last *Prosopis* contained no unstained pollen. The concentration of stained pollen only is given in fig. 1.

Exponential curves of the form $y = be^{-ct}$ were fitted by the method given by Bailey (1952) to the points representing pollen concentrations (y) in millions of grains per ml. after certain time intervals (t) for *Bombus hortorum*, *Bombus sylvarum* and the honeybee (*Apis mellifera*).

There is no significant difference ($P > 0{\cdot}05$) between the curves for *B. hortorum* and *B. sylvarum*. It appears that the *B. sylvarum* individuals were not starved so completely as the *B. hortorum*, since the curve for the former starts at a point representing a concentration lower than that actually fed. The curve for *B. hortorum* has a value of c which could be either positive or negative when the 5 per cent. fiducial limits of c are considered, and the curve therefore cannot be said to decline significantly. The curve for *B. sylvarum* certainly does decline, however, and when all things are considered it may be said that the two species filter pollen from their crop, but not very efficiently. *B. hortorum* may have been starved into a weak condition which could account for its apparently poor performance. It was not found easy to starve bumblebees with the same precision as was possible with honeybees. The latter became noticeably sluggish quite suddenly when their sugar supply failed, but the bumblebees tended to weaken imperceptibly to a condition from which they recovered only slowly after feeding.

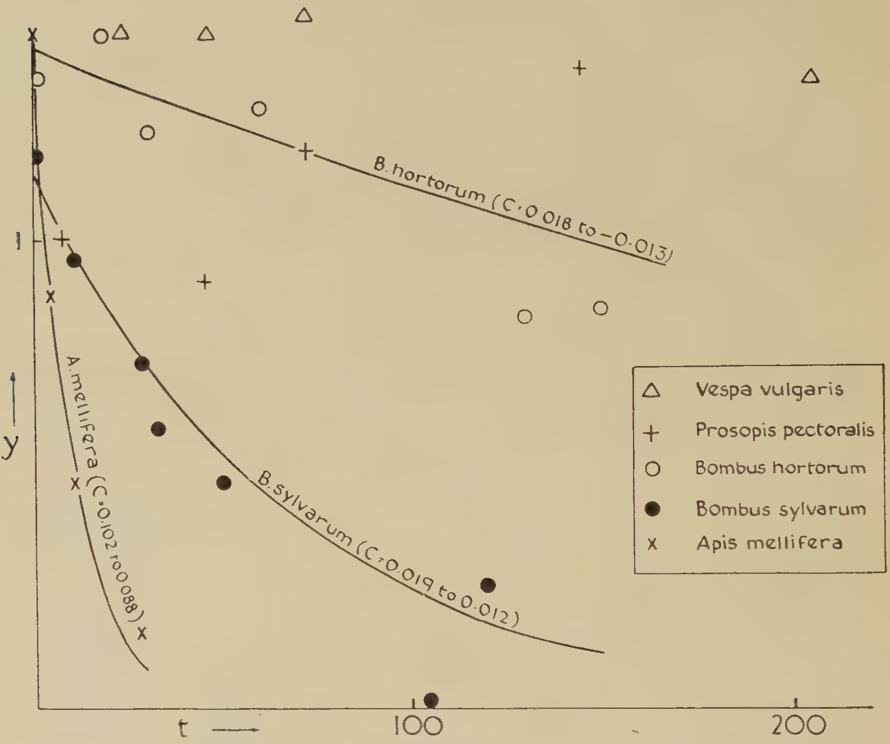

FIG. 1.—The rate of filtration of pollen particles from the crop by the proventriculi of various hymenoptera. The values of c given for each curve are the 5 per cent. fiducial limits. y in millions of grains/ml.; t in minutes.

The curve for the rate of filtration in honeybees is quite different from that of the bumblebees, and is virtually identical with the curve derived previously (Bailey, 1952) when bees were fed with the same volume of a similar pollen suspension.

The morphology of the proventriculi of these insects and of *Melipona iridipennis* is shown semi-diagrammatically in fig. 2. They are all fundamentally similar but the honeybee is unique in the possession of the fine comb of bristles (C) and the pouches (P) (fig. 2D). As described previously (Bailey, 1952) these features are responsible for the efficient filtration of pollen. Other *Apis* species (*A. dorsata*, *A. florea* and *A. indica*) have proventriculi virtually identical with the proventriculus of *Apis mellifera*.

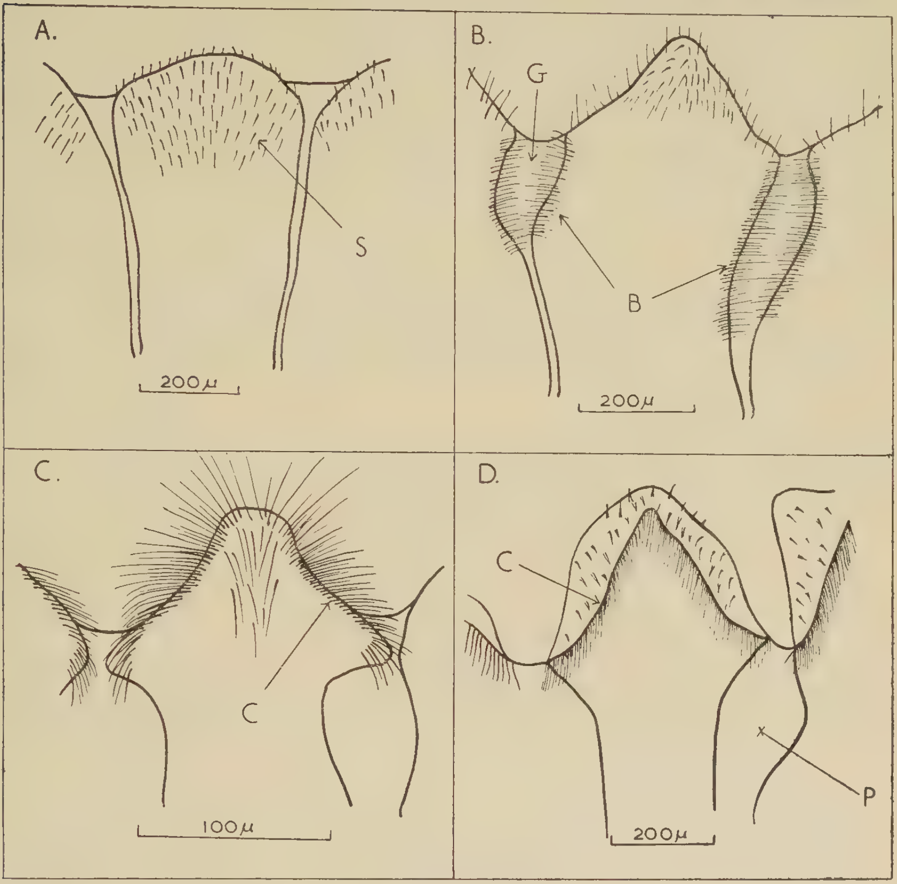

FIG. 2.—Internal aspect of one lip and associated structures of four representative proventriculi (semi-diagrammatic). A. *Vespa*. S = stubble of short bristles. B. *Bombus*. G = channel guarded by mesh of fine bristles, B. C. *Melipona*. C = comb of long bristles. D. *Apis*. C = fine comb of hairs. P = pouch.

The proventriculus of *Vespa* is relatively simple (fig. 2A) with only a short stubble of bristles (S) on the lips.

The proventriculi of *Prosopis* and other solitary bees (a *Megachile* and an *Andrena*) were similar to those in *Vespa* with no apparent filtration devices.

The proventriculus of *Bombus* species appeared somewhat different (fig. 2B). It is equipped with numerous long fine bristles (B) in a disposition which makes it appear as though pollen may be filtered to some extent by closing the lips after the organ has been filled and forcing the liquid out through channels (G) guarded with the bristles between the lips. There are no pouches, as in *Apis*, where pollen may be stored aside from the central lumen of the proventriculus, and the organ would thus be quickly choked with only a partially filtered mixture of pollen and honey.

The proventriculus of *Melipona* (fig. 2C) appears somewhat similar to that of *Apis*, but the comb of bristles (C) is not so precisely organised and the bristles are relatively long.

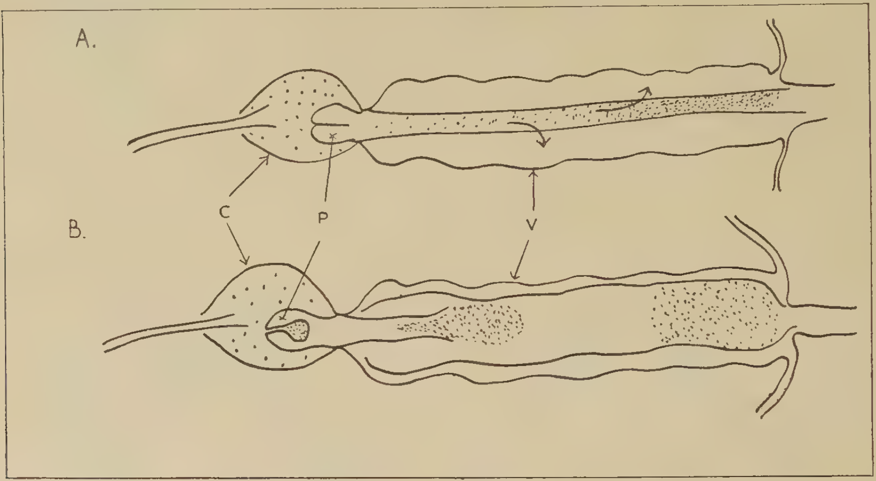

Fig. 3.—Diagrams of the alimentary canal. C = crop. P = proventriculus. V = ventriculus. A. *Vespa*, and also *Bombus* to a large extent, concentrate pollen principally by diffusion of liquid (indicated by arrows) through the peritrophic membranes. B. *Apis* concentrates pollen principally by the proventriculus.

It was seen that stained pollen fed in suspension to *Vespa*, *Bombus* and *Prosopis* was packed quite tightly within the narrow tube of concentric peritrophic membranes in the ventriculus a few minutes after feeding. This concentration was certainly not a consequence of filtration and bolus formation by the proventriculus, as in the honeybee, but was due to the outward diffusion of the liquid into the lumen between the membranes and the ventricular epithelium. Stained honey could readily be seen in this space outside the peritrophic membranes a few minutes after feeding. This essential difference between the concentration of pollen in the ventriculi of *Bombus* and *Apis* is illustrated in fig. 3.

Discussion.

The ability of various insects to filter particles from a liquid suspension can be correlated with the structure of the proventriculus.

This organ, in the form found in the wasp, occurs throughout the Hymenoptera with few exceptions, and its primitive function is most probably that of a valve allowing the insect to use its crop as a storage organ. Liquid food can then be passed back to the ventriculus as required.

The development of the filtering ability is probably secondary but is of great value when the insect must digest protein. Particles of protein can be conveyed to the ventriculus independently from their liquid medium. This means that the liquid (usually carbohydrate) intake can be adjusted to the requirements of the insect whilst solid protein is digested. There will also be minimum dilution and inhibition of proteolytic enzymes by sugar solutions.

The honeybee, and probably all *Apis* species, are able to digest relatively large quantities of pollen protein for the secretion of brood food which is the major protein food of the larvae. (Simpson (1954) has positive evidence that the amount of pollen eaten by honeybee larvae is quite inadequate for the protein requirements.) Adult honeybees are also able to lay down the digested pollen as a reserve in the fat-body during the winter (Lotmar, 1939) and there is sufficient evidence to show that these reserves have a prolonging effect upon the life of the individual (Maurizio, 1946).

Bombus species may digest a relatively small quantity of pollen compared with the honeybee, since the filtering ability of their proventriculus is relatively poor. They may be able to achieve some body maintenance with some prolongation of life, but it does not seem likely that they supplement larval diet with brood food.

It is evident that the manipulation of pollen in the honeybee community and probably the communities of all *Apis* species is an activity which is almost completely confined to the adult insect and has important consequences as a result. This could not be so without the efficient filtration mechanism of the proventriculus.

SUMMARY.

A comparison of the anatomy of the proventriculi of some Hymenoptera is made. *Apis mellifera*, *A. indica*, *A. florea* and *A. dorsata* have similar proventriculi. The morphology of the proventriculus of *Melipona iridipennis* approaches that of *Apis* species. The wasp and solitary bees have relatively simple organs with no apparent filtration devices. *Bombus* species have an arrangement of bristles in the proventriculus which seems to be responsible for its limited ability to filter.

The physiological significance of these varying capacities to filter particles from the crop and its important effect upon digestion of pollen by the honeybee is discussed.

ACKNOWLEDGMENTS.

I wish to thank Mr. J. Simpson for most valuable discussions and criticisms and Dr. C. G. Butler for the supply of tropical bees from Ceylon.

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DAILY CHANGES IN THE NUMBERS OF CHIRONOMID MIDGES AT KHARTOUM.

By D. J. Lewis, F.R.E.S.,[1] A. J. Henry[2] and D. N. Grindley.[1]

Chironomidae are a serious pest at Khartoum where they occur in vast numbers in the winter. They cause intense annoyance and probably give rise to coryza, asthma and other allergic conditions. Most of them are small midges, of which the commonest species is *Tanytarsus* (*Cladotanytarsus*) *lewisi* Freeman. The small chironomids are locally known as " nimitti " but this term is more correctly used for *Simulium griseicolle* Becker. When it is necessary to use a vernacular word and there is likely to be any confusion the common Khartoum chironomids may be called " green nimitti," most of them being of this colour.

The adults are usually most prevalent 50 to 300 metres south of the Blue Nile where they vary greatly in numbers, from dense swarms round the lights on bad evenings to small numbers which are scarcely noticeable. The object of the observations described here, nightly trapping of chironomids, was to find the cause of these fluctuations. It is hoped that this and other studies in progress will lead to their control.

Methods.

In early 1951 and during the winter of 1951 to 1952 a light trap with a 100 watt bulb was operated 100 metres from the Blue Nile and 7·9 metres above the ground on the south verandah of the Wellcome Chemical Laboratories which are situated on the south bank of the river and facing it. The trap, which has been described by Grindley (1952), was used for an hour and a half every evening from shortly after sunset. The catch was dried at 50° C. for five hours, and large midges and other insects removed, and the small midges were weighed. About 18,000 dried midges were found to weigh one gramme and numbers were calculated on this basis. Changes in the prevalence of certain species caused some error in this estimate, but it is considered that the results give a useful record of the frequency of " bad chironomid evenings." These usually resulted in an estimated catch of 200,000 or more and this figure was adopted as a criterion of bad evenings. The numbers trapped were large but were much less than the millions frequently seen round strong lights at ground level.

It was not practicable to estimate numbers from weighings in September and October (during the rainy season) because many minute insects other than midges were caught at that time.

Chironomids were also trapped on the north verandah of the Wellcome Chemical Laboratories, and notes were made on the prevalence of chironomids at a house some 600 metres west of the trap and 200 metres from the river.

Meteorological data were provided by the Government Meteorologist from observations made at the aerodrome which is one and a half kilometres from the river.

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[2] Formerly Government Analyst.

Results.

In the 1950–1951 season there were relatively few chironomids. Some bad nights were reported in December, and regular trapping began on 13th February (fig. 1). Only nine bad evenings were recorded. About 22nd April a grey species, considerably larger than *T. lewisi*, became common. Its presence did not seriously affect the records, however, because the numbers of chironomids after this date were small. *T. lewisi*, mainly females, was still present on 11th May when trapping was discontinued owing to dust storms and small catches.

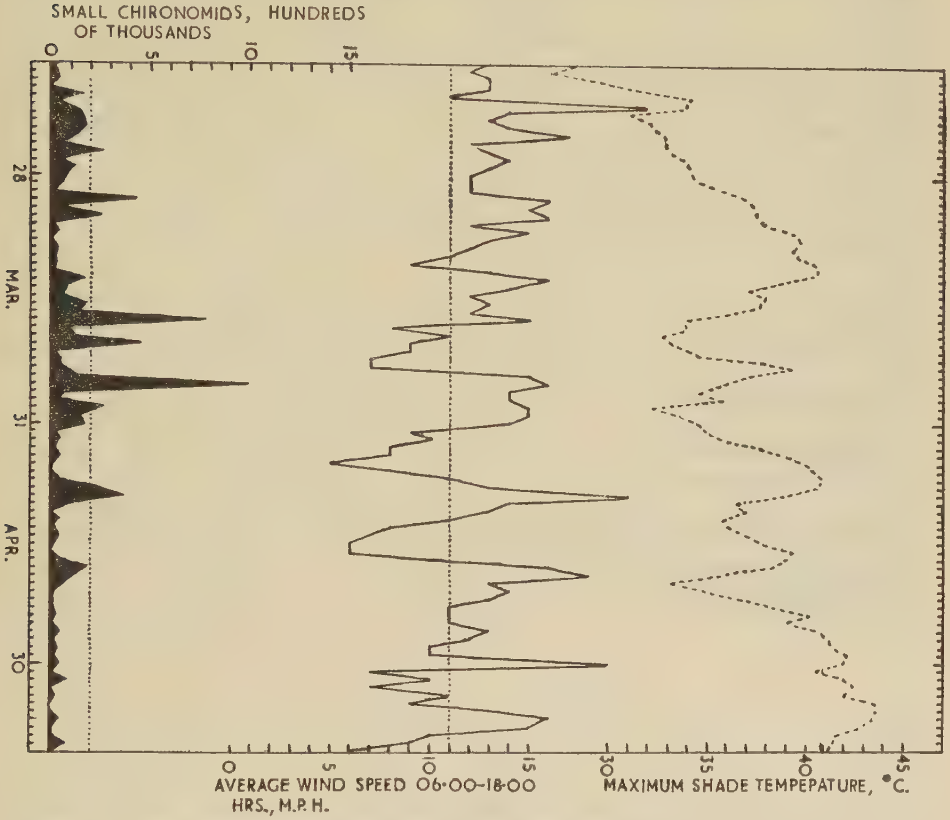

Fig. 1.—Numbers of small Chironomids (estimated from weights) trapped daily at Khartoum early in 1951, with wind speeds and maximum temperatures.

Trapping began again on 17th October, 1951, for the 1951–1952 season, but the numbers remained relatively small till the end of December. This season (fig. 2) proved to be a bad one, in which most of the bad nights were grouped into bad periods. *T. lewisi* was common but not always the commonest species. It accounted for the sudden increase at the end of May, long after the end of the normal "green nimitti" season.

The north verandah catches were very small, but after a day with a very light wind the number might rise to about 1 per cent of the catches obtainable on the south side on windy evenings.

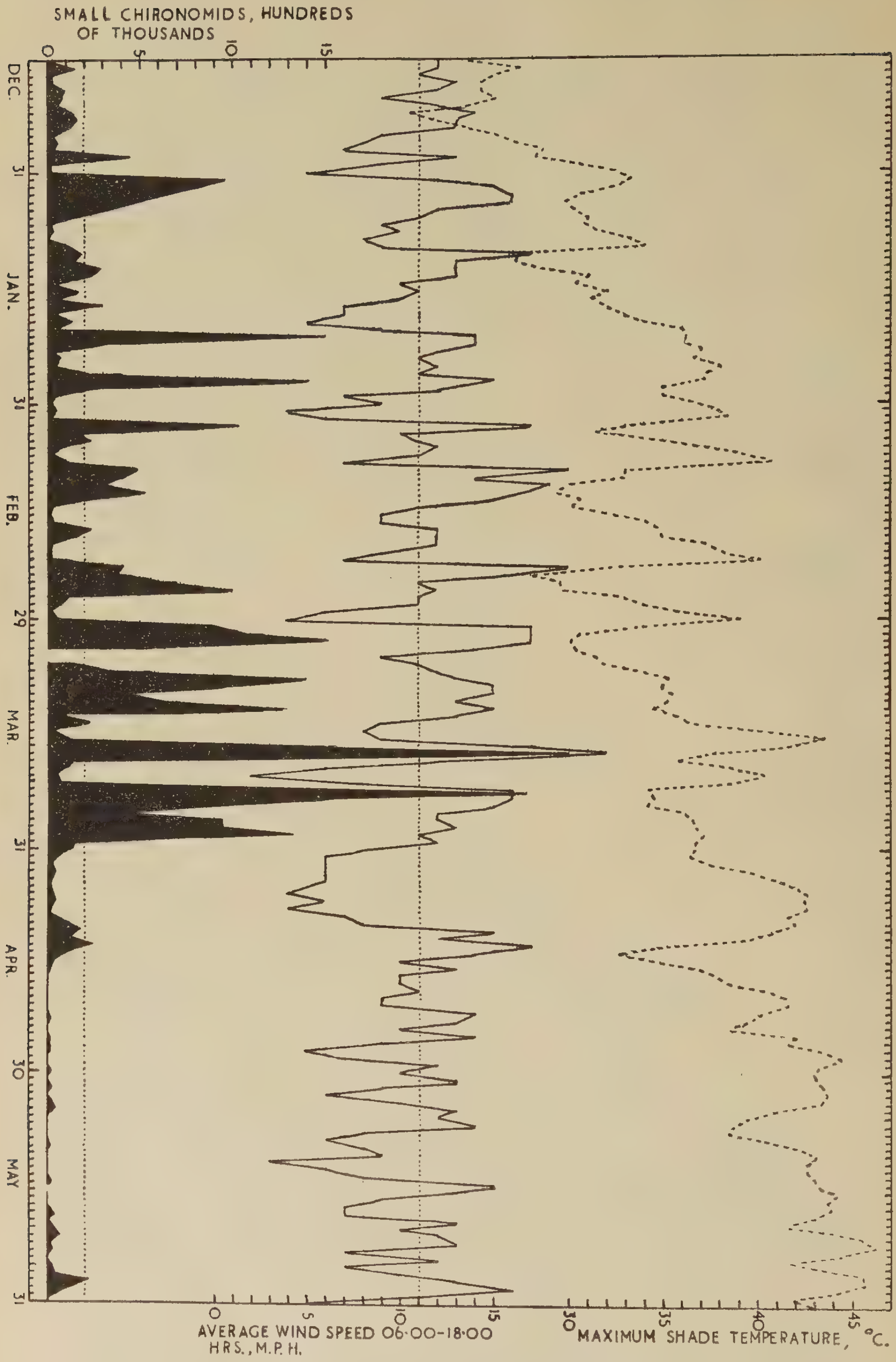

Fig. 2.—Numbers of small Chironomids (estimated from weights) trapped daily at Khartoum in the 1951–1952 season, with wind speeds and maximum temperatures.

In the above-mentioned general observations at the site west of the trap bad evenings frequently, but not always, corresponded with large catches in the trap. It was concluded that the results of the trapping represented conditions over a wide area but that there was considerable local variation. These general observations also showed that chironomids are sometimes common for short periods long after the " season " is over.

Discussion.

Several residents have tried to account for the fluctuations in chironomids, but their opinions are conflicting, probably because observations were made at different places and times for limited periods, and because the deciding factor was masked by others. Some of the reasons put forward may be true for certain isolated outbreaks. An observer at the west end of the town thought bad nights were associated with rises of the river level, and some people living further upstream reached the opposite conclusion. Several people thought bad nights were associated with warm weather following cold spells, and others that cold weather brought them on. Several attributed bad seasons to unusual temperatures.

Most or all of the chironomids breed in the Blue Nile, and, although conditions in the river determine the beginning of the season, there is no evidence that changes in this large body of water normally bring about the rapid fluctuations.

The midges, which are delicate and do not feed as adults, are exposed to severe atmospheric conditions, to high maximum temperatures and to relative humidities which fall as low as 3 per cent. (at the aerodrome). It was to be expected that temperature and humidity would affect the midges' length of life and so influence the fluctuations in numbers.

Meteorological conditions were considered in relation to the results of trapping, and strong winds appeared to be the chief cause of daily fluctuations, and to be so important as to mask any other effects. Changes of temperature seemed to have little or no direct influence.

Wind.

The prevailing wind from October to April in Khartoum is in the north, blowing from the river which flows from east to west at this point. The effect of wind is clearly seen in fig. 2. From 29.xii.51 to 31.iii.52 the average wind speed between 06·00 hours and 18·00 hours exceeded 11 miles per hour on 50 days and the estimated numbers of midges in the south trap exceeded 200,000 on the evenings of 40 of these days. During the same period the wind speed was 11 miles per hour or less on 43 occasions and the estimated number of midges was less than 200,000 on 37 of these occasions. Even when bad nights did not correspond to windy days in this way the figures usually showed borderline cases such as moderately strong wind followed by a moderate number of chironomids just exceeding 200,000. Apart from the effect of winds of this critical speed, catches showed little relation to wind speed. For example they showed no particular relation to wind speed at various times of day, namely early morning, forenoon or afternoon.

It is presumed that on a windy day more midges are blown ashore after emergence, and that during the day and early evening more are blown inland till they reach the shelter of gardens where they swarm round the lights when these are switched on. The low north-verandah catches, which increase with light breezes, support this theory. Since the catches (in both traps) comprised several species with different emergence times it is particularly striking that one factor can be seen to play a dominant part in determining outbreaks. On the other hand the multiplicity of species and environmental conditions discourages any further analysis of the results.

It may seem surprising that this simple explanation of " nimitti evenings " was not self-evident. A line of trees, however, partly screens the houses from the north wind, and only slight changes in wind speed sometimes cause great increase in the chironomids. Furthermore the results are probably depending partly on wind speed some hours before the appearance of the insects.

Temperature.

There is no obvious relation between bad evenings and maximum temperatures, but fig. 2 shows a tendency for bad evenings to occur when a rise of temperature is interrupted or is followed by a sudden fall. Probably the bad evenings are caused by strong winds which are associated with temperature changes in various ways. A " cold front " from the Mediterranean area may cause a strong wind, or a strong wind may reduce the air temperature locally.

Both seasons ended about the time when the maximum temperature commonly exceeded 40° C. and it may be that few chironomids can survive such weather till the evening.

SUMMARY.

Tanytarsus lewisi Freeman and other small chironomids are a serious pest at Khartoum, chiefly from 50 to 300 metres south of the Blue Nile where their numbers vary greatly from evening to evening.

The results of catching the midges with a light trap are described. Various possible causes of fluctuations in numbers are considered and it is concluded that a bad evening usually follows a day with an average wind speed of more than 11 miles per hour during which the midges are blown to shelter in the affected area.

ACKNOWLEDGMENTS.

We are very grateful to many Khartoum residents, particularly Dr. and Mrs. C. B. Drew and Mr. F. F. de Paravicini, for general information about the prevalence of chironomids, and to the Government Meteorologist for meteorological information.

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METAMORPHOSIS IN THE INTEGUMENT OF CATERPILLARS WITH OMISSION OF THE PUPAL STAGE.

By K. K. Nayar, M.A., Ph.D.

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If the young nymph of *Rhodnius*, in the first to the fourth instar, be deprived of its corpus allatum by decapitation and be then joined in parabiosis with a moulting nymph in the fifth or final instar, it is caused to moult, and its general integument undergoes a complete metamorphosis, with the development of adult characters. Metamorphosis in the wings, external genitalia and ovaries, however, is incomplete ; these structures are clearly not yet " competent " to undergo an entirely normal metamorphosis (Wigglesworth, 1934, 1936).

In *Dixippus* (Pflugfelder, 1937) and *Leucophaea* (Scharrer, 1946), on the other hand, the young insect deprived of its corpus allatum undergoes two moults before the adult form is assumed. According to Scharrer (1946, 1948) this is because the tissues are not yet competent to undergo metamorphosis ; whereas Wigglesworth (1948, 1952) has suggested that there may be sufficient juvenile hormone still persisting in the blood or tissues for metamorphosis to be partially inhibited during the first moult after the corpus allatum has been removed.

A similar example is afforded by the Lepidoptera. In this group, removal of the corpora allata in the young larva is always followed by the formation of the pupa ; development of adult characters does not occur until the second moult (Bounhiol, 1938 ; Fukuda, 1944). Whether this invariable occurrence of the pupal stage in Lepidoptera is a necessary step in the process of metamorphosis is not known. In *Rhodnius*, the relatively small morphological differences between the nymphal instars are brought about by differences in the timing and concentration of the secretion of the juvenile hormone by the corpus allatum (Wigglesworth, 1936, 1952). Piepho (1950, 1951) has suggested that the larva, pupa and imago in Lepidoptera are similarly produced in the presence of three different concentration levels of the juvenile hormone.

Now the general surface of the body in the adult Lepidopteron, like that in *Rhodnius*, is formed by the same cells which have laid down the cuticle of the larva and pupa. If the foregoing explanation is correct it ought, therefore, to be possible to induce the caterpillar to transform directly into the moth. This might not be possible for elaborate structures like the appendages or wings, that are derived from imaginal discs, (which may not be sufficiently well grown to be " competent " to undergo normal metamorphosis) but it should be possible in the general integument. This is made all the more likely by the fact that if the larva of the honey-bee is decapitated at the appropriate time the normal pupal stage may be omitted, and incomplete imaginal characters developed when the larva moults (Schaller, 1952).

The purpose of the present work was to test this possibility by transplanting pieces of the integument of caterpillars into the body wall of pupae.

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MATERIAL AND METHODS.

Three insects were used for this study, namely *Galleria mellonella*, *Ephestia kühniella*, and *Pieris brassicae*. Healthy, active, third or fourth instar larvae were used as donors, and newly formed pupae, about one to two days old, were used as hosts for the implants. Meso- and meta-thoracic terga were cut out from the live larvae with fine forceps-scissors. The integument was cut out with clean edges, was freed from adhering fragments of large tracheae and fat body, and then kept in insect-Ringer, to be used immediately afterwards. The etherised pupa was fixed on to a slide by thin pieces of plasticine, and a piece of tergum was cut out with a sharp-edged bent lancet, from the first, second or third abdominal segment. The larval integument was then placed in position, in a number of cases at right angles or reversed, and the area was covered over by a thin film of paraffin (39° C.), care being taken not to occlude the spiracles of the segment. The operated pupae were kept individually in tubes plugged with cotton wool, and were stored in an incubator at 25° C. In some cases, single segments from the abdomen of the larvae were used as transplants.

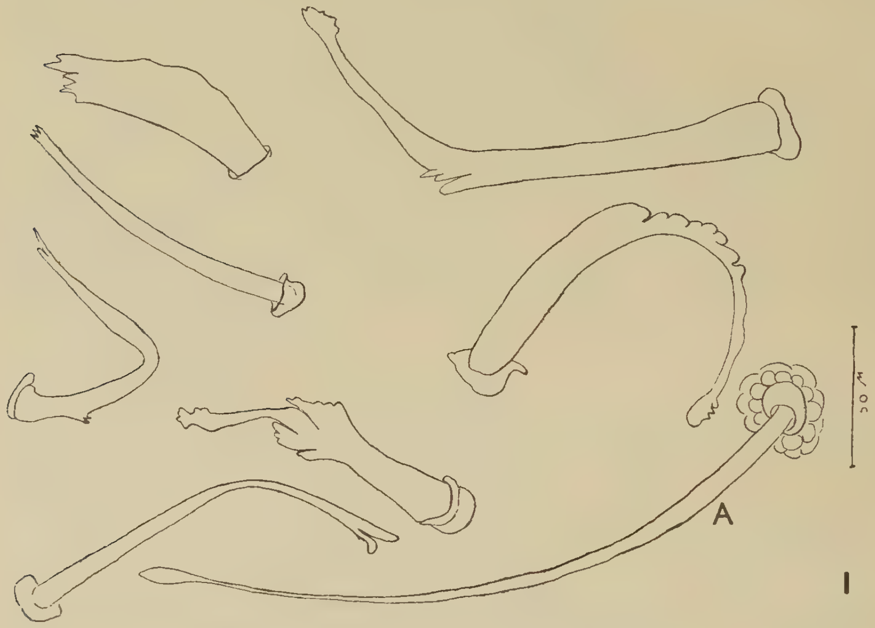

FIG. 1.—*Ephestia kühniella*. Camera lucida figures of seta-like scales on the moulted integument of the transplant from larvae. (A) Camera lucida figure of the seta from the normal pupa.

On emergence, the adult insect in each case was etherised, and the operated segment with the adjacent one was cut out, placed flat on a slide, and fixed in Carnoy's fluid. Then the fragment was upgraded, cleared in xylene and mounted in canada balsam.

OBSERVATIONS.

During earlier experiments, using *Ephestia kühniella*, there was a high percentage of mortality, and the reason for this was traced to a heavy infection of a sporozoan parasite which multiplied enormously in the region of the graft, leading to blackening and subsequent death. This was overcome by using larvae reared from freshly isolated eggs. Such larvae were distinctly different in being pink-coloured, unlike the pale yellow and comparatively inactive stock larvae used earlier.

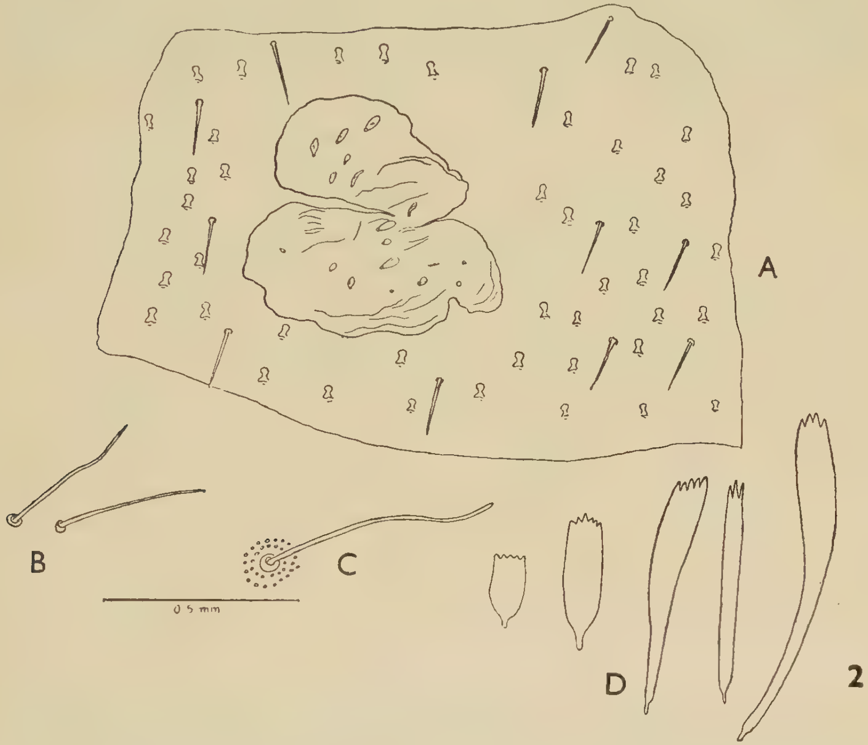

FIG. 2.—*Galleria mellonella.* (A) Camera lucida outline of the first abdominal segment showing the graft from the larva. The double segment of the transplant (meso- and metathoracic segments) is indicated by a faint groove and notches near the middle. Scale-sockets alone are represented on the normal portions of the segment of the host, scales are omitted. (B) Camera lucida drawing of setae from larval mesothorax. (C) Camera lucida drawing of a seta from pupal mesothorax. (D) Camera lucida drawings of the normal scales of the mesothorax of adult.
Note.—All these figures are drawn to the same scale of magnification.

In a number of cases it was observed that the region of the graft developed a thin and transparent sheet, apparently formed by the invasion of epidermal cells from the cut edges of the pupal integument. A large majority of these showed dark brown islands of hard material, presumably the dead graft, which appeared as a hazy, sclerotized mass.

In other experiments, the grafts took well, and became incorporated in the integument of the host. Traces of the red pigment of the larva could still be seen in the epidermal cells, and where double segments had been implanted, a groove or space, marking the position of the intersegmental region, was clearly visible. There was, therefore, no doubt whatever that these areas were derived from the implant and not from regeneration by the host.

In *Ephestia kühniella*, the implant after moulting was found to have developed setae of abnormal type. These setae are rather long, fleshy and brown in colour, and they often show a certain amount of flattening, resembling a miniature scale. They do not end in a fine point, as in the larva, nor in a slight spatula, as in the pupa (fig. 1A), but in a frayed tip (fig. 1). Many of them showed fine indentations along the margins, or terminally.

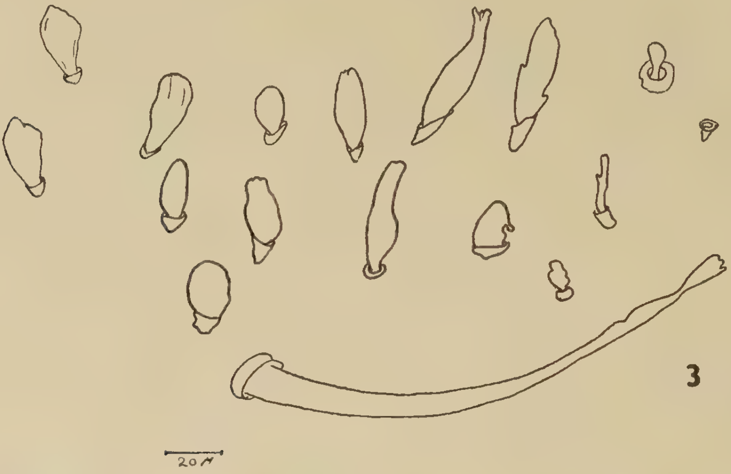

Fig. 3.—Camera lucida drawings of the tiny scales on the transplant figured in 2 (A).

It is worth noting that these fleshy setae which appear on the implant resemble the abnormal scales which are formed in those regions where the adult skin has regenerated. These may arise from typical scale-sockets and appear like the fleshy setae, but shorter and yellowish in colour. Various gradations of these are visible on the regenerate, leading up to the normal, well formed scales towards the edge of the segment.

In *Galleria mellonella* the moulted larval skin was still more interesting. Here the region showed an assemblage of structures which were unmistakable scales. Many of them were tiny, but with distinct flattened bodies and arising from tiny sockets (figs. 2A and 3). Along with these were a number of seta-like, fleshy processes, halfway between scales and setae.

In *Pieris brassicae* the graft blackened and was sloughed off in a number of experiments, the wound being covered solely by regenerated integument. In other experiments where the transplant had grown on, the region of the graft developed scale-like setae (fig. 4). These resembled elongated scales which had failed to develop completely. They were fleshy, flattened and frayed at the tip, the whole process being curved around a longitudinal groove and not truly cylindrical.

From these results it will be seen that the larval integument of the early stage (third or fourth instar) caterpillar could be induced to transform directly into the imaginal type. In *Galleria mellonella* small but definite scales, implanted in sockets, have been developed on the graft which has moulted along with the pupal host, while in *Ephestia kühniella* and *Pieris brassicae* special structures, with flattened and lobed endings which resemble more a scale than a seta, and quite unlike larval and pupal setae, have been formed. This production of scales, or scale-like integumental structures, shows that a direct change to the imaginal type is possible in the early larval integument, and that the latter is " competent " to undergo metamorphosis.

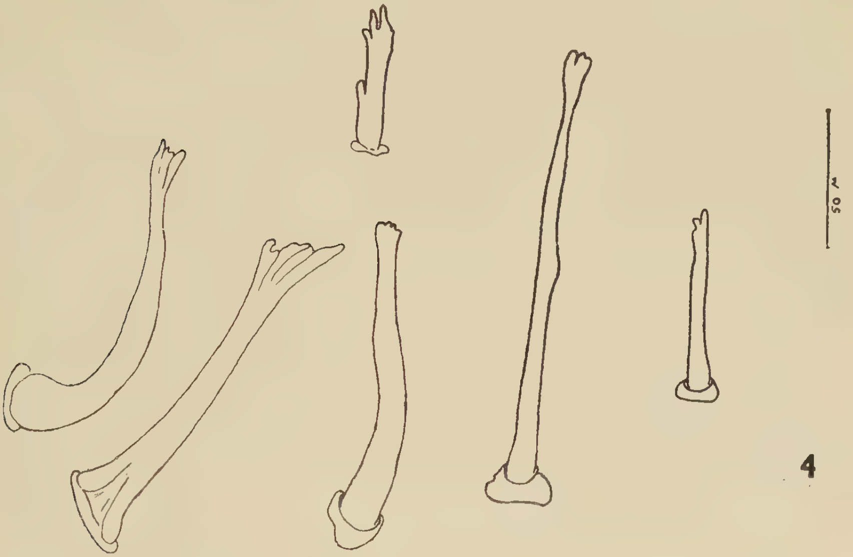

Fig. 4.—Camera lucida drawings of the seta-like scales on the larval transplant of *Pieris brassicae.*

SUMMARY.

Integument transplanted from third and fourth instar caterpillars of *Ephestia kühniella*, *Galleria mellonella* and *Pieris brassicae* to the respective young pupae, moulted and laid down an adult or adult-like cuticle with scales or structures intermediate between setae and scales. This represents metamorphosis of the larval integument without the intervention of a pupal stage and indicates that the integument of the larva is " competent " to undergo metamorphosis directly to the imago.

ACKNOWLEDGMENTS.

This problem was suggested to me by Prof. V. B. Wigglesworth, C.B.E., F.R.S., and the work was done in the Sub-Department of Entomology, Department of Zoology of the University of Cambridge. I am greatly indebted to Prof. V. B. Wigglesworth for guidance, constant encouragement and for help in the preparation of this paper. My thanks are due to Mrs. E. M. Sale for a regular supply of pupae for the daily experiments.

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ON THE STRUCTURE AND FUNCTION OF THE RESPIRATORY HORNS OF THE PUPAE OF THE GENUS *PSEUDOLIMNOPHILA* (DIPTERA: TIPULIDAE)

By H. E. Hinton, Ph.D., F.R.E.S.

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No other insect pupae that have been described have respiratory horns that in structure or function resemble those of the genus *Pseudolimnophila*[1]. I am unable to agree with Alexander's (1920, p. 836) claim that, "*Pseudolimnophila*, the Ulomorphae, and *Pilaria* have the pronotal breathing horns very long and slender with the tips split into divergent flaps." I have bred *Pilaria scutellata* Staeger, *P. discicollis* Meig., *P. adjuncta* Walk., *P. nemoralis* Meig., *P. filata* Walk., and *P. batava* Edwards. The respiratory horns of the pupae of none of these species have divergent flaps that resemble or function like those of *Pseudolimnophila*. In all of these species of *Pilaria* the apical slit extends down only one side of the horn, and consequently surface tension forces, even on those species that have the apices less rigid and sclerotised, can only widen to a relatively slight extent the longitudinal slit at the apex. From the figure given by Alexander of *Ulomorpha pilosella* O.S., it seems clear that the respiratory horns of this species are very similar to those of some of the species of *Pilaria*, e.g., *P. discicollis* Meig. and *P. batava* Edw.

The larvae of both of the British species of *Pseudolimnophila* live in mud rich in organic matter, or in submerged decaying vegetation on the banks of streams or in bogs, as do the North American species of the genus. They feed on decaying vegetable matter, and in this respect they are exceptional amongst the Hexatomini.[2]. The larvae pupate where they are feeding, but if they are actually submerged by a layer of free water, they tend to move to a drier place. This has been noticed both in the field and in my cultures. They can, however, pupate successfully when just submerged. The pupae are normally found more or less covered with mud, but with the tips of the respiratory horns exposed to the air. The places where they are found will often be flooded, particularly after a heavy rain. In this event the pupae float and tend to drift towards the edge. The pupae or pharate adults can work their way out of the water if they drift into a gradually inclined edge.

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[1] The genus *Pseudolimnophila* Alexander (1919) is usually included amongst the subgenera of *Limnophila* Macq. The structure of its immature stages, especially that of its larvae, would, however, seem to preclude its inclusion in the genus *Limnophila*.

[2] The great majority of the Hexatomini are predaceous, but *Epiphragma ocellaris* L. and *Austrolimnophila ochracea* Meig. feed on decaying wood. I have often taken the larvae of *Limnophila* (*Pilaria*) *batava* Edw. with that of *P. lucorum* Meig., and on one occasion (Crickhowell, Breconshire, 24.iv.1954) the larvae of *L.* (*P.*) *filata* Walk. with that of *P. sepium* Verrall. Both of these species of *Pilaria* ingest large amounts of vegetable matter and may not be predaceous like the other species included in the subgenus. The structure of the head capsule of both species, however, is characteristic of that of the genus *Limnophila* (*s. lat.*).

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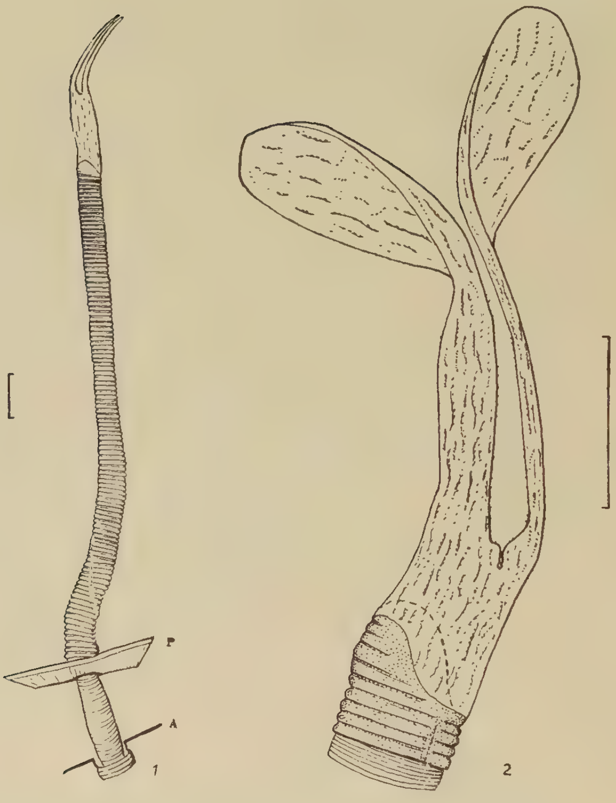
The lengths of ten pupae and their respiratory horns were as follows:

Pupa (without horn). mm.	Respiratory horn. mm.
8	2·3
8	2·6
9	2·6
9·5	2·6
10	2·4
10	3·0
11·5	3·2
12	3·0
14	3·5



Figs. 1–2.—(1) Outer view of left respiratory horn of the pupa of *Pseudolimnophila lucorum* Meig. (2) Inner view of same with the apical flaps slightly diverging. (A) Adult cuticle; (P) pupal cuticle. Lines next to figures refer to a length of 0·20 mm.

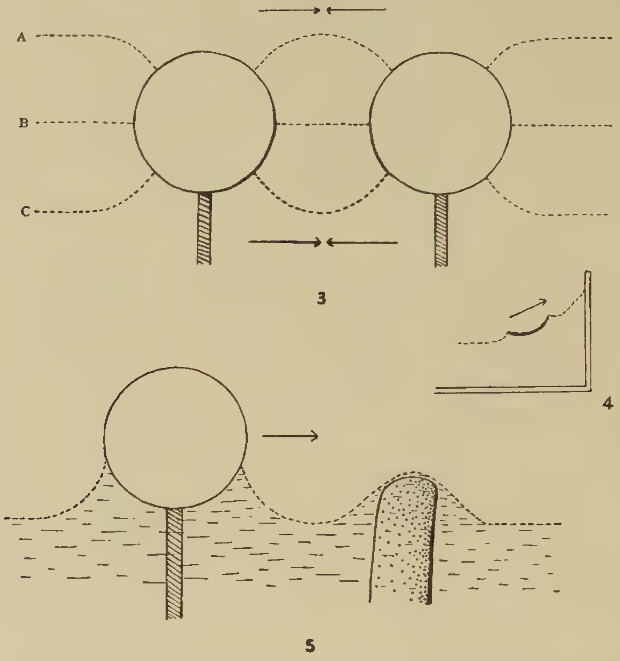
The structure of the respiratory horn is shown in figs. 1–2. The horn consists of an apical membranous part and a proximal heavily sclerotised tube that is strengthened by fairly regular annular thickenings. The annular thickenings are interrupted only at the "seam." The membranous apical part consists of a proximal tube and two flat apical flaps (fig. 1), separated by an outer and an inner slit. The outer slit extends nearly to the basal half of the membranous part. The inner slit (fig. 2) extends nearly to the basal fifth of the membranous part. The parts here called flaps extend only to the lower limit of the outer slit. The cuticle of the flaps is slightly but distinctly thinner than that of the proximal membranous part. Most of the "pupal period" is passed as a pharate adult, when the adult insect is using the pupal respiratory horns. At the pupa-adult moult the epidermis at the base of the pupal horn contracts away from the pupal cuticle, so that there is always a length of pupal trachea, about 0·3–0·5 mm. long, that extends external to the adult cuticle between the adult spiracle and the base of the pupal respiratory horn (fig. 1). The junction of the tracheal cuticle with that of the respiratory horn is at the base of the apical membranous part.

With few exceptions the pupae were less dense than the water. They nearly always float upwards with the long axis normal to the surface, although once they break the surface film the centres of buoyancy and gravity are such that they rarely remain perpendicular to the surface. Beneath the surface, the flaps of the horns are kept pressed together by hydrostatic pressure, and usually only a very fine film of air is retained between them.

As the tip of the horn penetrates the surface the adhesion of the water to the outer surface of the flaps enables the surface tension to pull them apart. The flaps are pulled apart to about the level of the outer slit, when they rest horizontally upon the water and at right angles to the long axis of the horn. As the flaps are pulled apart by surface tension, the lumen of the proximal part of the membranous horn down to the level of the inner slit is slightly increased in size. This increases the displacement of the pupa to a slight extent. When the flaps are spread apart on the surface film the buoyancy of the pupa is such that some part of the inner surface (now the upper surface) of a flap is bent upwards, and so projects above the general level of the water. The adhesion of the water to the outer surface (now the lower surface) of this part of the flap is sufficient to raise a mound of water above the general level of the water. Such mounds so distort the surface film that the pupae, without any activity on their part, are enabled to take advantage of the free energy of the surface film, and travel up the inclined surface of the water surrounding any object to which they pass sufficiently close. This effect is independent of the angle of contact of the water at the edges of the flaps, which is much more than 0° and much less than 180°.

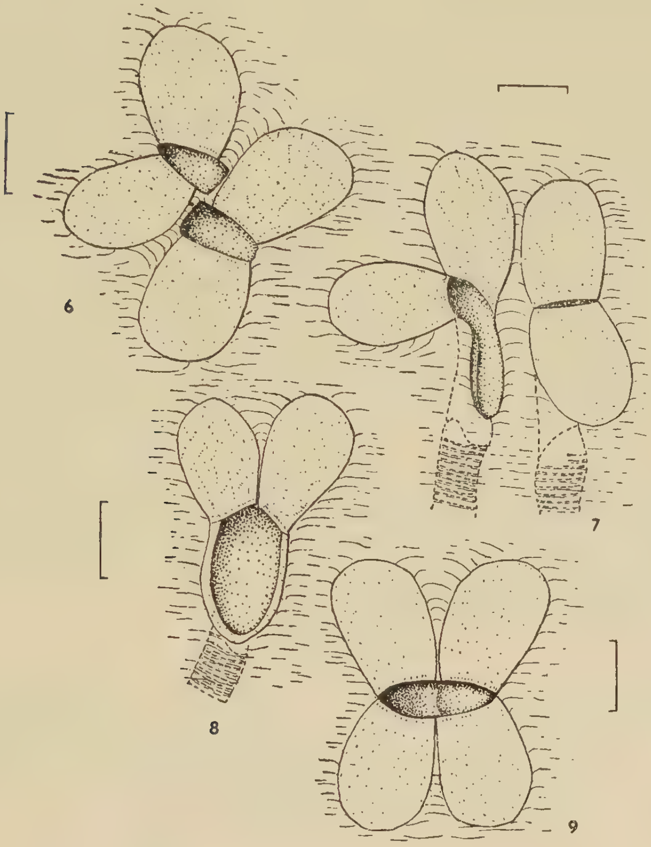
The pupa is thus provided with an automatic trapping device, which tends to prevent it from floating freely and tends, in the long run, to bring it against the bank or other projection, upon which it can wriggle its way out of the water. The contours of the mounds of water raised by the flaps of the pupae were always more or less circular, so that the pupae were pulled up the inclined water surfaces surrounding wettable objects irrespective of the orientation of the body of the pupa to the wettable object. The buoyancy of the great majority of the 36 pupae examined was such that a relatively large mound of water was raised beneath the flaps, and they thus travelled at a considerable speed up the inclined surfaces brought near them. When the surface of the water was inclined downwards, instead of upwards towards the object projecting from the water, the pupae were repelled from it if sufficiently close. The general principles underlying the phenomena described here are shown in figs. 3–5.

The shape and size of the openings to the air formed by the respiratory horns depend not only upon the orientation of the pupae to the surface but



Figs. 3–5.—(3) Relation between two floating spheres of three different densities. The nature of the surface of each is assumed to be such that the angle of contact is 90°. At " B " the water surface between them is approximately flat, the free energy of the system is at a minimum, and the spheres neither move to or away from each other. At "A" and "C" the surface film is distorted in such a fashion that the spheres move towards each other as the free energy of the system diminishes. When the menisci around the spheres are unlike, they repel each other. (4) Illustration of the way in which a small oblong beetle (*Tachyporus hypnorum* F.) is able to travel up the inclined surface of the water at the edge of a petri dish. It arcs its body as shown so that, irrespective of considerable variations in the angle of contact, it raises a mound of water under its head and another under the tip of its abdomen. These mounds of water are raised at the expense of bending the surface film downwards along the sides of its body. The beetle will thus travel rapidly without any activity on its part, up the inclined surface as soon as it is near enough to the edge so that between it and the edge there is no stretch of relatively flat surface. It was found that the weight of all small terrestrial insects dropped on the surface of the water was so distributed that the surface film was bent upwards at some points and downwards at others. It was usually bent upwards at the head and tail and downwards at the sides. Stability is achieved by the lateral edge of the body and the legs. It is by distorting the surface film in this fashion that small terrestrial insects, which cannot take wing from the surface, and cannot lower the surface tension behind them by secretion (like *Dianous* and *Stenus*), are not permanently trapped in small pools of water. (5) Distortion of the surface film by a totally submerged object. The totally submerged object has only a solid-liquid interface and therefore no angle of contact. It serves to illustrate the point that it is the distortion of the surface film, and not the angle of contact, with which small insects are chiefly concerned. The line of contact of the water on the cuticle is normally not shifted, even when the angle of contact is considerably altered in the process of distorting the surface film.

also upon the shape of the horns. Since not only are the horns bent slightly differently in most pupae, but those of the right and left sides are rarely exactly similar, many variations in the shape of the openings were noted. Some characteristic variations are shown in figs. 6–9. If the long axis of the pupa is more or less normal to the surface, the flaps open at right angles to the long axis of the horn. If the apices of the horns are not parallel, the openings are independent, as shown in fig. 6. If, however, the apices are more or less parallel a common air-tube may be formed, as shown in fig. 9. Such a common air-tube may extend below the surface for the full length of the inner slit (fig. 2), since in this position the slits of the right and left horns are in conjunction. When the flaps are in this position water is excluded from the narrow space left between the opposed hydrofuge edges of the right and left flaps.



Figs. 6–9.—Drawings made with the aid of a camera lucida of the apices of the respiratory horns of living pupae. Lines next to figures refer to a length of 0·20 mm. For further explanation, see text.

If the pupa comes to rest at a small angle from the horizontal and is either turned slightly to one side, or the horns are bent slightly differently, the right and left horns open differently at the surface. An example of this is shown in fig. 7, in which the left horn has the whole of the inner slit open to the air, and the right horn has only a very narrow transverse opening to the air. In some specimens the right and left horns were so shaped that, when the pupa was turned to one side, only the apex of one horn could reach the surface in any particular position (fig. 8). A few of the pupae collected in the field were found to have the inner slit lengthened proximally, apparently by an accidental tear, and in these the opening to the air when the inner side was uppermost was largest (fig. 8).

When the pupae are totally submerged, the flaps are pressed together by hydrostatic pressure, and usually only a very fine film of air remains between them. The proximal membranous tube maintains its shape at a depth of 12 inches, a depth which the pupa probably rarely encounters in its natural habitat, even when it is unable to free itself of entangling vegetation when it is flooded. The total air-filled membranous area of the horn is relatively large (fig. 1), and it therefore seems likely that it may function in certain situations as a gill. Nothing is yet known of the permeability of the membranous part. When the pupa is in its normal habitat in mud rich in organic matter its own activity will ensure that the horn is open to the air and is not used as a gill. A spiracular gill in this kind of environment, which is usually poor in oxygen, might be supposed to be a considerable danger to the pupa: the gill would extract oxygen from the pupa as soon as the oxygen tension of the mud fell below that of the tissues of the pupa. It thus appears likely that if the membranous part ever functions as a gill it does so only when the pupa is flooded and is unable for one reason or another to reach the surface. In the event of flooding the oxygen tension of the water may be high enough for the survival of a submerged pupa. It may be noted here that all previously known species that have well developed spiracular gills live only in waters of high oxygen tension (summary in Hinton, 1953).

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COMMUNICATION BETWEEN HONEYBEES. I: THE RESPONSE OF CROP-ATTACHED BEES TO THE SCENT OF THEIR CROP.

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Introduction.

Early observations (e.g. Spitzner, 1788; Dujardin, 1852) indicated that foraging honeybees could inform their hivemates about the presence of good sources of food. A detailed investigation of this ability was carried out by von Frisch (1923), who observed that successful foragers, having given away samples of their booty, began to dance in a manner which encouraged the recipients to leave the hive in search of further supplies. Furthermore, bees which were already attached to a particular crop could be incited to go in search of it, during some resting period, by contact with a successful forager which had just returned from that crop; contacts with bees coming back successfully from other crops were not effective.

In the experiments now presented the stimulating effect of the scent itself is separated from the effect of the dances and the nectar or pollen supplies.

Method.

On successive afternoons, after 14.00 hrs. G.M.T., about 500 bees from one colony were trained in equal numbers to two Petri dishes filled with sugar syrup. Both dishes were 100 yards from the hive, and 50 yards apart; the bees going to them were marked with differently coloured paints. The syrup in one dish was scented with benzyl acetate, and that in the other with methyl benzoate.

After two or three afternoons of training the dishes were put down at the same positions during the mornings. All bees then arriving were immediately captured and recorded, but as the bees were by then time-conditioned (Beling, 1929) they came to the dishes only in small numbers. At some time during the morning 1 ml. of a 10 per cent. solution in ethylene glycol of one of the two scents was pipetted into the hive, and the number of marked bees arriving at both dishes before and after the treatment provided an estimate of the inciting effect of the scent. Marked bees went only to the dish to which they had been trained. The captured bees were liberated at the end of each morning test so that they could be available for subsequent tests.

There were three experiments. Any deviations from the standard method are given in the description of the results.

Results.

Experiment 1.—Bees were trained on 20th and 21st June, 1952; the two dishes were put out, scented but syrupless, from 09.30–11.00 hrs. G.M.T. on 23rd June, and were observed alternately for 15-minute periods; 25 bees visited each dish in this time. Training occurred on that afternoon.

On 24th June 1 ml. 10 per cent. benzyl acetate was pipetted into the hive at 09.55 hrs., when both dishes were put out and filled with scented syrups. The following bees (all correctly marked) arrived at the dishes and were captured :

	09.55–10.10 hrs.	10.10–10.25 hrs.	10.25–10.40 hrs.	10.40–10.55 hrs.	Total.
B.A. dish	3	9	3	5	20+
M.B. dish	2		2		4—

Training continued on the two following afternoons, and the experiment was repeated on 26th June, methyl benzoate being pipetted into the hive at 09.55 hrs. Bees came thus :

	09.25–10.10 hrs.	10.10–10.25 hrs.	10.25–10.40 hrs.	10.40–10.55 hrs.	Total.
B.A. dish	3	2	1	2	8—
M.B. dish	2	1	2	0	5+

Experiment 2.—Bees were trained on 20th and 21st August, 1952. The two dishes were put out, with scented syrup, at 10.35 hrs. on 22nd August ; they were watched continuously, and all bees captured on arrival. At 11.05 hrs. benzyl acetate was pipetted into the hive.

The following bees were captured :

Before treatment.		After treatment.			
10.35–11.05 hrs.	Dish.	11.05–11.20 hrs.	11.20–11.35 hrs.	11.35–11.50 hrs.	Total.
37	B.A.	12	11	10	33+
38	M.B.	6	5	4	15—

Bees were fed at both dishes that afternoon, and the experiment was repeated next day (23rd August) using methyl benzoate as the introduced scent.

The results were :

Before treatment.		After treatment.			
09.30–09.45 hrs.	Dish.	09.45–10.00 hrs.	10.00–10.15 hrs.	10.15–10.30 hrs.	Total.
15	B.A.	6	13	20	39—
6	M.B.	11	11	10	32+

The bees were not fed on that afternoon or on the subsequent day, and the experiment was repeated on 25th August, again using methyl benzoate as the introduced scent.

The following bees were then captured :

Before treatment.		After treatment.			
09.30–09.45 hrs.	Dish.	09.45–10.00 hrs.	10.00–10.15 hrs.	10.15–10.30 hrs.	Total.
11	B.A.	1	1	1	3—
6	M.B.	1	0	3	4+

The bees were fed at the dishes on that afternoon, and 120 more bees were marked at each dish. Next day the experiment was again repeated, using benzyl acetate as the introduced scent, with the following results :

Before treatment. 08.45–09.45 hrs.	Dish.	After treatment. 09.45–10.00 hrs.	10.00–10.15 hrs.	10.15–10.30 hrs.	10.30–11.00 hrs.	Total.
13	B.A.	29	18	3	8	58+
24	M.B.	9	18	7	8	42–

Experiment 3.—130 bees were marked at each dish on the afternoon of 28th July, 1953, and 120 more on the following afternoon. Control captures were made at both dishes from 08.30–10.30 hrs. on 30th July, and the bees were fed at the dishes that afternoon. It rained all day on 31st July, and the experiment was carried out on 1st August, using benzyl acetate as the scent introduced into the hive.

The results were :

Before treatment.			After treatment.					
30th July 08.30–10.30 hrs.	1st Aug. 08.30–09.00 hrs.		09.00–09.15 hrs.	09.15–09.30 hrs.	09.30–09.45 hrs.	09.45–10.00 hrs.	10.00–10.15 hrs.	Total.
28	1	B.A.	0	5	11	18	10	44+
34	2	M.B.	1	1	0	4	3	9–

CONCLUSIONS.

In two out of the seven tests, more control bees than experimental bees were recovered, but in one of these two (23rd August, 1952) the proportion of experimental bees increased from 29 per cent. in the control period, to 45 per cent. in the treatment period ; in both of them (26th June and 23rd August, 1952) the contrary experiment on the previous day may have partially inhibited the time-conditioning of the control bees. The results, considered as a whole, indicate that the addition of the scent to which the bees were trained approximately doubled the chance that they would go to their feeding place outside the visiting time to which they had been trained.

Thus the mere presence of the training scent in the hive, in the absence of either food sharing or dancing, can encourage crop-attached bees to go to their crop.

DISCUSSION.

The elaborate methods of communication and recruitment to crops which are now known to exist among honeybees (von Frisch, 1923, 1946) must have evolved in simple stages, and a primitive method of communication (which could exist even in social insects which did not pass food from one to another) may have been recognition of the scent of food brought into the community by other members. Food sharing would increase the amount of information so provided, and excited movements by successful foragers, to activate the other bees, would be a further improvement. These excited movements could then come to bear some automatic relation to distance or direction travelled, which could also be appreciated by the other bees ; the essential characteristics of communication between foragers, as we now understand them, would then have evolved.

SUMMARY.

Bees from one colony were trained to forage, in equal numbers, from two Petri dishes 50 yards apart. One dish was supplied with sugar syrup scented with benzyl acetate, the other with sugar syrup scented with methyl benzoate.

Training took place after 14.00 hrs. G.M.T. only, but when the bees had been sufficiently time-conditioned the dishes were put down in the morning. One or other of the two scents was then pipetted into the hive ; the addition of the scent to which it had been trained doubled the chance that the bee would visit its feeding place outside the usual training time.

The role of scent and dancing in recruitment to crops is discussed.

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LARVAE OF THE BRITISH TRICHOPTERA.—46.

By N. E. Hickin, Ph.D., F.R.E.S.

Micropterna lateralis Stephens (Limnephilidae).

In a previous paper, describing the larvae of *Limnephilus centralis* Curtis, I gave details of my finding the larvae of *Micropterna lateralis* Stephens at Chartley Moss (Anglesea Coppice, Stowe, Staffs.) with Mr. James Edwards on 6th April 1953. From larvae then collected and maintained in an aquarium, a female *Micropterna lateralis* emerged on 25th May, Mr. Kimmins identifying it. Mr. Edwards informs me that he believes the only previous Staffordshire record of this insect is one taken at light at Burnt Wood by Mr. H. L. Burrows about twenty years ago.

Mosely in his description of the adult, refers to the " brown freckles " on the anterior wings. The freckles are, however, much paler than the general ground colour of the wings and can be described as " cream-yellow."

Case.—18 larval cases collected are very similar in appearance, and range from 16 mm. to 19 mm. in length and 3½ mm. to 4 mm. in width. They consist of pieces of dead grass, leaves and bracken fronds ; the pieces are more or less uniform in size and of strongly contrasting colours—light yellowish brown to very dark brown, all the pieces fitting closely so that the exterior surface of the case is smooth. Some of the pieces are, however, placed obliquely. The case is circular in cross section and is only very slightly curved (in some instances the curvature is hardly apparent), and the posterior end is partially closed, leaving a large irregular opening. At the anterior opening the dorsal surface extends over the ventral surface.

Larva.—Length 16 mm.–18 mm., width 3 mm. *Head* orange chestnut, eyes situate in pale areas more readily visible from the sides. Margins of aboral end of clypeus approximately parallel before convergence to the vertex. Base of antennae white, and conspicuous white area at base of mandibles. *Labrum :* Middle of anterior margin deeply incised, and the small lateral dark marks present in *Micropterna sequax* McLachlan are absent. *Thorax :* Sclerotised parts yellowish-brown, pronotum of uniform colour, except for the greyish transverse groove, but in *M. sequax* the posterior two-thirds is darker in colour than the anterior one-third. Anterior and posterior margins of mesonotum more heavily sclerotised than in *M. sequax.* Prosternal horn yellow. *Legs :* Prothoracic legs short and stout, meso- long and meta- slightly longer than meso- but not quite so stout. *Abdomen :* Lateral line from 3rd to 8th abdominal segment but not very prominent, the hairs being very short.

Summary.

The larva of *Micropterna lateralis* Stephens is described and figured, and a figure of the adult is given.

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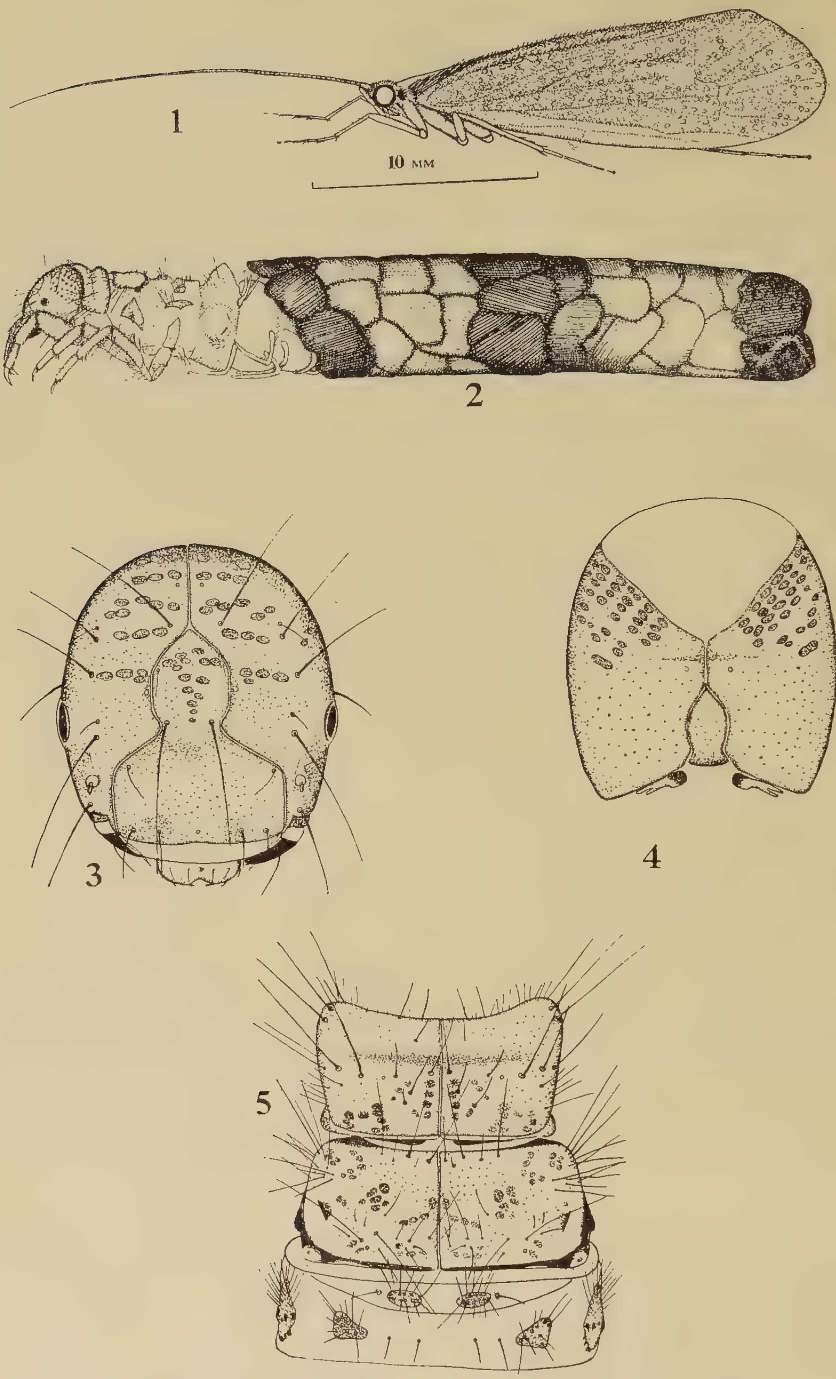

Figs. 1–5.—*Micropterna lateralis* Stephens. (1) Adult. (2) Larva in case from the side. (3) Head of larva from the front. (4) Head of larva from behind. (5) Thoracic nota of larva.

TAXONOMY OF THE LARVAE OF THE BRITISH SPECIES OF THE GENUS *RHYACOPHILA* (TRICHOPTERA).

By Mrs. Jean C. Mackereth

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(*Communicated by* T. T. Macan, M.A., Ph.D., F.R.E.S.)

There are four species of *Rhyacophila* found in Britain: *R. dorsalis* Curtis, *R. septentrionis* McLachlan, *R. obliterata* McLachlan and *R. munda* McLachlan. The larvae of two of these species have been described: *R. dorsalis* by Hickin (1942) and Marlier (1943), and *R. septentrionis* by Ulmer (1909), Rousseau (1921) and Nielsen (1942).

None of these authors has described more than one of the species. The purpose of the present article is to present the results of a comparative examination of all four.

Distinctions were established on last instar larval skins, recovered from the pupal cases from which male adults had emerged. Some pupae died before emerging, but males could be identified if the adult genitalia had formed. Mosely's book (1939), was used for the identification of the male adults. The females cannot be separated.

When good distinguishing characters had been found from these cast skins, whole larvae were used. All available specimens were examined under a binocular microscope, and mounted material was examined under higher magnification.

The descriptions and key are based on the fifth instar. Means of distinguishing the species in earlier instars have not yet been worked out.

On the upper side of the anterior half of the head there is a conspicuous median sclerite which is referred to as the clypeus by Rousseau, Ulmer and Hickin. Nielsen (1942, p. 268), who is followed by Marlier, concludes, after a study of the muscle insertions, that frons and clypeus have fused, and accordingly calls the sclerite the fronto-clypeus.

Descriptions and Comparisons of the Species.

Rhyacophila dorsalis Curtis.

Material: Ford Wood Beck, WL,[1] 11 cast skins, 19 whole larvae; Wilfin Beck, WL, 2 cast skins, 1 whole larva; Tenter Beck, WL, 1 cast skin; Tullithwaite Beck, WL, 3 whole larvae; Hog House Beck, WL, 2 whole larvae; Pull Beck, WL, 2 whole larvae; Dan Beck, WL, 1 whole larva; Black Beck, WL, 1 cast skin; Stock Ghyll WL, 1 cast skin, 2 whole larvae; Tom Ghyll WL, 1 whole larva; Whelpside Ghyll, CU, 5 whole larvae; Naddle Beck, CU, 6 cast skins; R. Rothay, WL, 2 whole larvae; R. Brathay, WL, 18 cast skins, 2 whole larvae; R. Troutbeck, WL, 4 whole larvae; R. Leven, WL, 1 whole larva. R. Derwent, SN/DM, 6 whole larvae; Beck near Crooklands WL, 1 cast skin; R. Ribble, MY, 4 whole larvae; small stream Porth Clais, PB, 2 cast skins; peaty burn at Pettister, Unst, SI, 1 cast skin, 2 whole larvae.

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[1] CU = Cumberland, DM = Durham, MY = Mid-Yorkshire, PB = Pembroke, SI = Shetlands, SN = South Northumberland, WL = Westmorland.

The head, which tapers slightly towards the anterior end and has a slight constriction about the level of the eyes, is creamy yellow. There is a characteristic dark brown marking at the aboral end of the fronto-clypeus, the shape of a spade or heart in a pack of cards. At the posterior end of the genae there are pale indistinct dots on a dark brown area (fig. 1*D*). The anterior edge of the fronto-clypeus is straight with minute projections at each end.

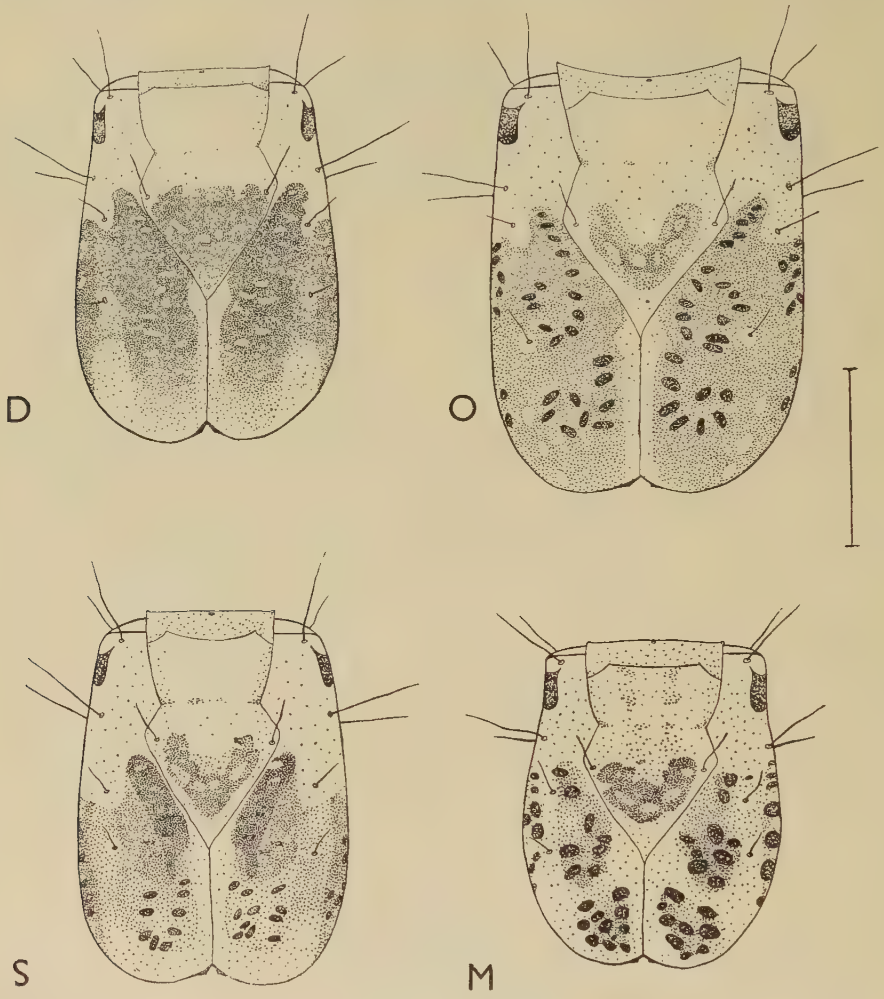

FIG. 1.—Heads; *D, Rhyacophila dorsalis; O, R. obliterata; S, R. septentrionis; M, R. munda.*

The pronotum is sclerotised and creamy yellow, with an irregular brown patch extending from the posterior margin to slightly beyond the mid-line.

This patch is covered with small darker dots which vary in intensity in different specimens, but which are indistinct in most fully grown larvae.

The colour of the meso- and metathoracic segments and the abdomen is variable; most specimens are yellowish-green ventrally and darker purplish-green dorsally. On each side of these segments there is a many-filamented gill (fig. 2*D*). The number of filaments varies in different specimens; in last instar larvae there are between eight and thirty. The number of filaments in each gill on each side of a segment is rarely the same, and the difference is as much as six in some specimens.

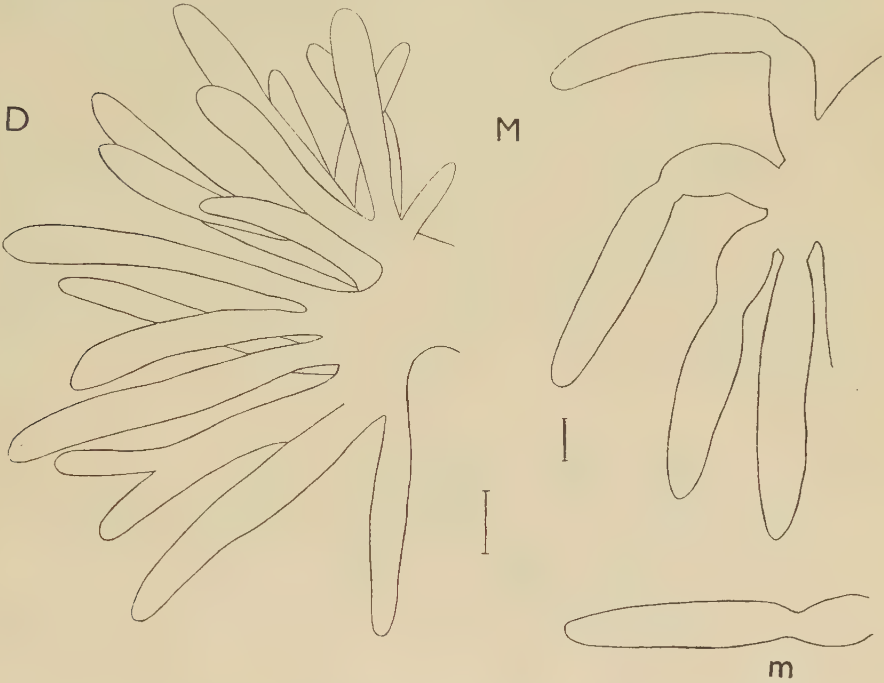

Fig. 2.—Gills; *m*, thoracic gill of *R. munda*; *M*, abdominal gill of *R. munda*; *D*. thoracic gill of *R. dorsalis*.

The legs are short and robust. All the segments bear black hairs of varying lengths, and each claw has a short spur attached to the inner side.

The long curved anal claw is made up of two segments; the proximal segment has a long thread-like bristle on its inner surface; the distal segment bears two, and occasionally three robust spines (fig. 3*D*). Attached to the outer side of the anal claw there is an auxiliary spine, which is long and curved (fig. 3*S*).

R. obliterata McLachlan.

Material: Ford Wood Beck, WL, 5 cast skins, 13 whole larvae; Cowside Beck, MY, 6 cast skins; Black Beck, WL, 3 cast skins; Stock Ghyll, WL, 2 whole larvae; Pull Beck, WL, 1 whole larva; Moss Burn, WL, 6 whole larvae.

The head of *R. obliterata* differs from that of *R. dorsalis* in that it is straight- and parallel-sided; the fronto-clypeus is broader, and its anterior edge is concave; the posterior parts of the genae are light brown, with brown dots forming a pattern as shown in fig. 1*O*. The marking at the aboral end of the fronto-clypeus is light brown and crescent-shaped.

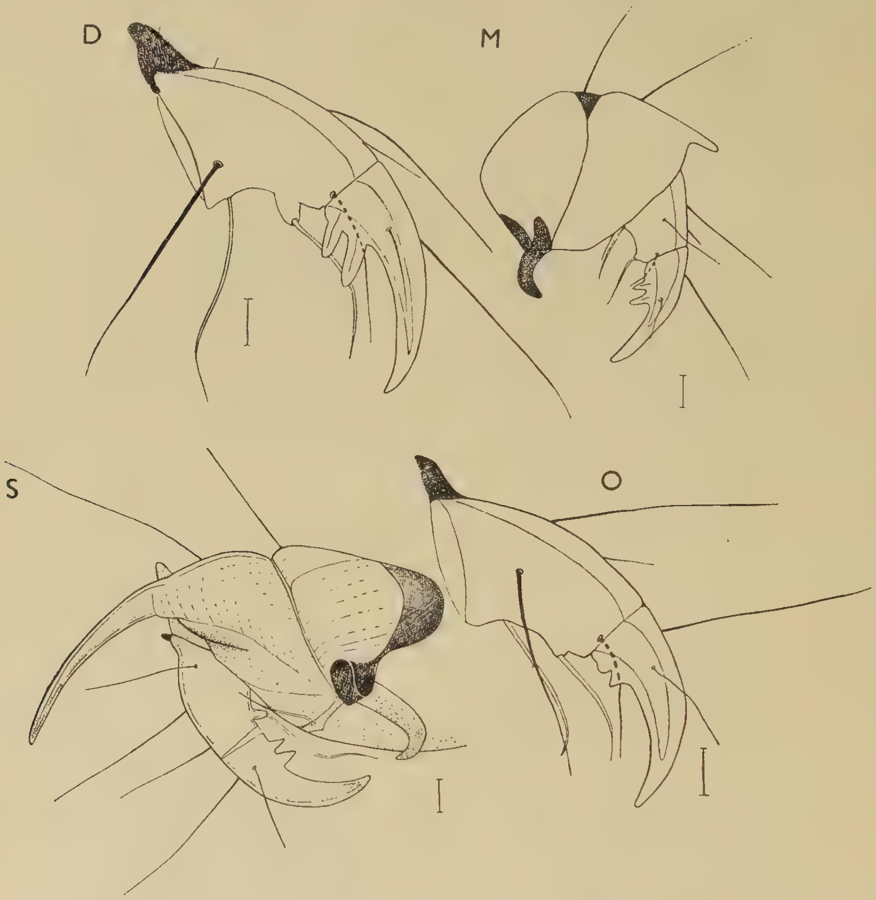

Fig. 3.—*D*, anal claw of *R. dorsalis*; *O*, anal claw of *R. obliterata*; *M*, anal claw and auxiliary spine of *R. munda*; *S*, anal claw and auxiliary spine of *R. septentrionis.*

The two spines on the distal segments of the anal claw are stumpy compared with those of *R. dorsalis*, but this difference is only apparent in fully grown specimens (fig. 3*O*).

The young instars have the characteristic parallel-sided head but cannot be distinguished from *R. dorsalis* on the other characters.

R. septentrionis McLachlan.

Material: Malham Tarn Inflow, MY, 6 cast skins and 6 whole larvae.

This species is difficult to distinguish from *R. dorsalis*. The head (fig. 1*S*) tapers slightly towards the anterior end, but is not constricted at the level of the eyes. The brown marking at the aboral end of the fronto-clypeus is crescent-shaped as in *R. obliterata* in all the British specimens seen. Of the Belgian specimens, some had this crescent shape, but darker ones had the heart-shaped marking as in *R. dorsalis*. According to Nielsen, this marking can be heart-shaped or crescent-shaped. At the posterior end of the genae there are dark brown dots ; these are evident on both the British and Belgian specimens, and are also illustrated by Nielsen and Ulmer. No such dark dots have ever been seen on a specimen of *R. dorsalis*, and this does therefore provide a clear distinction between the two.

R. munda McLachlan.

Material : Small stream, Porth Clais, PB, 1 cast skin, 4 whole larvae ; Plantation Beck, Greenodd, WL, 9 whole larvae.

R. munda is very distinct from the other three species of the genus in having the gills on each side of the meso- and metathorax with a single filament (fig. 2*m*), and those on the abdominal segments with four (fig. 2*M*). The auxiliary spine is very short as fig. 3*M* shows. The head (fig. 1*M*) is even more constricted at the eyes than that of *R. dorsalis*. The head pattern is bold, the basic colour being orange-yellow. The abdomen is light green ventrally and darker green dorsally.

KEY TO FULLY GROWN LARVAE.

1. Gills on meso- and metathorax with one filament, those on the abdominal segments each with four filaments (figs. 2*M*, *m*). Auxiliary spine on anal claw very short (fig. 3*M*) . . . . . **munda** McLachlan
–. Gills on meso- and metathorax and abdomen with many filaments (fig. 2*D*). Auxiliary spine on anal claw long and curved (fig. 3*S*) . . 2.
2. Sides of head straight. Anterior edge of fronto-clypeus concave (fig. 1*O*) . . . . **obliterata** McLachlan
–. Sides of head converging. Anterior edge of fronto-clypeus not concave (figs. 1*D* and 1*S*) . . . . 3.
3. Markings on posterior dorsal side of genae dark brown with indistinct light dots. Sides of head converging and constricted at the level of the eyes (fig. 1*D*) . . . . **dorsalis** Curtis
–. Markings on posterior dorsal side of genae brown with distinct darker brown dots forming a pattern (fig. 1*S*). Sides of head converging but not constricted at the level of the eyes (fig. 1*S*) **septentrionis** McLachlan

ACKNOWLEDGMENTS.

I wish to acknowledge my indebtedness to Dr. T. T. Macan for all his help and advice during this work ; to Mr. D. E. Kimmins of the British Museum (Natural History) for his help with the identification of the adults ; to Mr. P. F. Holmes for sending me specimens of *R. septentrionis* from Malham ; to Mons. G. Marlier for sending me specimens of *R. septentrionis* from Belgium ; and to Mr. V. M. Brown for sending me specimens of *R. obliterata* from north Westmorland.

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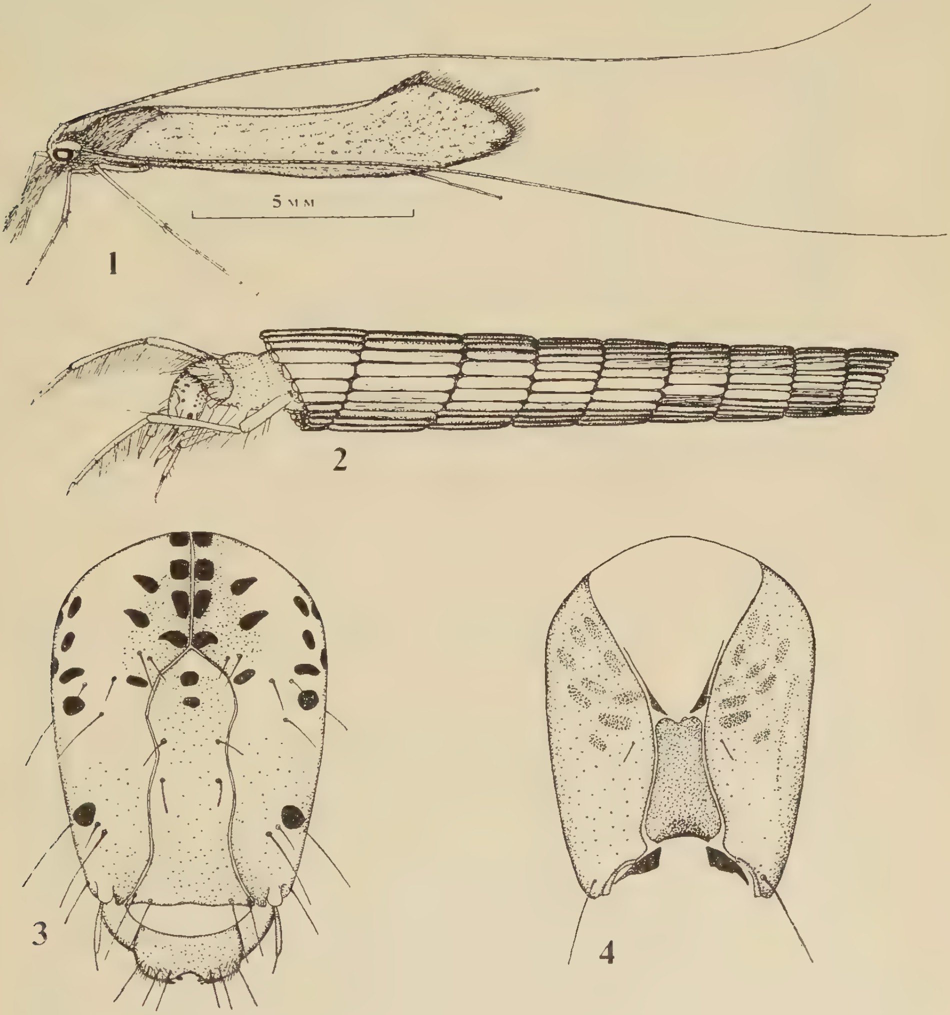
LARVAE OF THE BRITISH TRICHOPTERA.—47.

By N. E. Hickin, Ph.D., F.R.E.S.

Triaenodes conspersa Rambur (Leptoceridae).

Adults of this very local species were collected by Mr. A. Peacey during 1952 from the banks of the river Coln at Welford, Gloucestershire. On 9th April, 1953, we examined the trailing weeds in this fast-flowing trout-stocked river for larvae, at the spot where the adults had been taken, but we were unsuccessful.



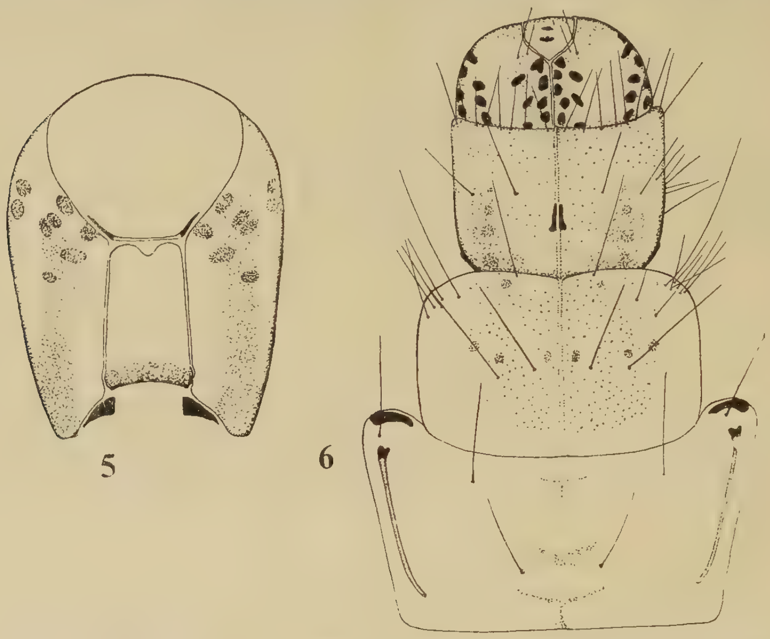
Figs. 1–4.—*Triaenodes conspersa* Ramb. (1) Side view of adult. (2) Larva in case. (3) Head of larva from the front. (4) Head of larva from beneath.

PROC. R. ENT. SOC. LOND. (A). 29. PTS. 10–12. (DEC., 1954).

Then on 9th June, 1953, I received from Mr. Peacey a number of *conspersa* larvae which he had collected from a point a few hundred yards upstream from where our previous attempts to collect had been made. Both Mr. Peacey and I were unsuccessful in rearing the larvae through, but as there is no doubt of their identity a description of these larvae is given here.

Larva.—Length 12 mm. Width 1·5 mm. (Ulmer puts the size as slightly larger.) Head light golden brown with dark brown marks.

Case.—Of small pieces of cut stalk arranged spirally in a similar manner to that of *T. bicolor* Curtis. Length 17·5 mm. Width at front 2·4 mm, tapering towards posterior end.



FIGS. 5–6.—(5) Head of larva of *Triaenodes bicolor* from beneath. (6) Head and thoracic nota of larva of *Triaenodes conspersa.*

Larva very similar to that of *Triaenodes bicolor* already described in this series of papers. It has also the habit of being able to swim through the water with its case, by means of rapid beats of its long, heavily-fringed metathoracic legs. The larvae may, however, be easily differentiated as follows: the marginal bands of dark marks on either side of the clypeus in *bicolor* are absent in *conspersa.* Substantial differences exist between the two species when the head is viewed from beneath. In *conspersa* the gular sclerite is dark grey in colour with concave lateral margins, and the width at the aboral end is much less than that at the oral end. Whereas in *bicolor* only the oral end of the gular sclerite is dark grey, the lateral margins are straight and the width at the aboral end is little less than that at the oral end. The longitudinal dark bands stretching almost the whole length of the underside of the head in *bicolor* are absent in *conspersa.*

SUMMARY.

The larva of *Triaenodes conspersa* Rambur is described and figured, and a figure of the adult given.

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VISION AND BLINDNESS IN MOSQUITO LARVAE AS INDICATED BY THE SUBMERGING REFLEX.

By A. W. Leftwich, B.Sc., F.Z.S.

(*Communicated by* W. J. Hall, C.M.G., M.C., D.Sc., F.R.E.S.)

Introduction.

It has long been known that the larvae of many mosquitoes exhibit an *alarm reaction*. When a shadow passes across the water they instantly submerge. As observed by Bates, Holmes and others, this alarm reaction takes place in response to a diminution of light but not to an increase. Any slight diminution of intensity hardly perceptible to the human eye brings it about. On the other hand, the sudden switching on of a bright light has no effect. As observed by S. J. Holmes, the action is not a mere submerging reflex but also involves a definite phototactic movement. If the light is shining on one side, the larvae will move away from that side if disturbed, although if left alone for a time, they will gradually return to the position of greatest illumination. There is therefore a positive phototaxis when at rest, but a negative phototaxis when disturbed. According to Bates different species of mosquito vary in the degree to which they exhibit this alarm reaction. *Culex urichii* Coquillet is the most sensitive whilst *Culex metempsytus* Dyar does not show the action at all.

That the reaction is not a mere fear of something moving is shown by the fact that if a dark object is moved horizontally over some larvae resting on the surface, they will not submerge, but if it is brought nearer, thus cutting off more light, they instantly do so.

It will be seen that, using a species which normally reacts in this way, the reaction furnishes a ready means of finding out whether the eyes are functioning properly ; whether they respond to certain frequencies of light ; whether they become blind or fatigued, etc. With such objects in view a number of experiments were performed using larvae and pupae of *Culex pipiens* L. in various stages of development.

Structure of the Eyes.

The larval eyes of the *Culicidae* have been adequately described by Zavrel (1907) and by Raschke (1887). In all species there is a pair of lateral ocelli and a pair of compound eyes anterior to these. The ocelli which develop in the embryo while still within the egg are at first the only eyes. During the 2nd instar, however, the compound eyes appear, gradually enlarging and approaching the ocelli as the number of ommatidia increases. In fourth instar larvae and in pupae, the compound eyes are fully developed and overlap the anterior rims of the ocelli. It is probable that in this state both types of eye are functional, but that the compound eyes, occupying a much larger area than the ocelli, are the more important of the two.

The compound eyes are of the normal or *eucone* type. That of *Aëdes communis* De Geer has been described in detail by Raschke. It differs little from the compound eyes of the vast majority of insects. Each ommatidium has the usual cuticular lens secreted by epidermal corneagen cells. Beneath this is a short crystalline cone with a bluntly rounded apex pointing inwards, the whole cone being surrounded by a number of cells forming a sheath. Beneath the crystalline cone are the pigmented retinal cells collectively forming another cone down the centre of which is the optic rod or rhabdom. Each retinal cell is continuous with a post-retinal axon fibre leading straight to the corresponding optic lobe of the brain.

The ocelli each consist of a single cuticular lens beneath which is a gelatinous layer and a number of pigmented cells. From these, likewise, axon fibres go to the optic lobes of the brain. The nerves from the compound eye and from the ocellus form two branches which join a short distance in to form a single nerve tract to the brain.

INTENSITY OF LIGHT PERCEPTIBLE.

Using a large number of third and fourth instar larvae of *Culex pipiens*, it was found that they all instantly submerged if a card was interposed between them and the daylight casting a shadow over the tank. The experiment was repeated using a 90 candle-power incandescent lamp placed at various distances from the larvae. It was found that when the lamp was further than one foot away, there was no alarm reaction except from a few of the smaller larvae. Nearer than one foot the reaction was immediate in all cases. It can therefore be concluded that an intensity of 90 foot candles is about the minimum perceptible intensity of light in the case of the larger larvae, but that the smaller ones are slightly more sensitive, possibly due to the thinner cuticle.

RANGE OF COLOUR VISION.

A number of coloured light filters of glass and cellophane were placed momentarily in front of tubes containing miscellaneous larvae and pupae of *C. pipiens* in daylight. The following colours were used, but the filters were not monochromatic: violet, dark blue, light blue, dark green, light green, amber, red, dark red. In every case the alarm reaction was as strong as that obtained by interposing an opaque object. The stimulus for submerging seems to be a reduction of intensity of light of any colour. It does not necessarily follow, however, that the insect can distinguish between the various colours, but it evidently perceives a reduction in brightness due to the absence of any colour.

When a bottle of carbon disulphide is passed in front of the insects, all larvae and pupae instantly submerge. This liquid is a strong absorber of ultraviolet light and was used by Sir John Lubbock to show that ants can perceive this type of light. It is probable therefore that mosquito larvae also are sensitive to it and perceive a reduction in its intensity.

FATIGUE OR HABITUATION.

The submerging reflex was repeated at short intervals until the larvae and pupae refused to respond. It was found that in most cases this was after about a dozen times. The time necessary for recovery was about 5–10 minutes. This "fatigue" is not a phenomenon of the retinal pigment or of the optic nerve. If this were the case long exposure to light would cause it, but in fact it is the repeated response to reduction of light which brings it about. It cannot therefore be regarded as true fatigue, but rather that the insect becomes habituated to the repeated stimulus and after a while refuses to respond to it. There is still, however, an immediate submerging reaction if the water is touched or disturbed in any way. The muscular and nervous systems as a whole seem to be unaffected.

There is no very satisfactory theory to account for this habituation. A possible suggestion is that lack of oxygen in the insect's system brings about a reflex action causing it to rise to the surface, where it normally remains by a *phototonus* or stiffening of the muscles brought about by light, a phenomenon which is well-known in many other insects which take up strange attitudes and remain perfectly motionless when exposed to light. A reduction of light causes the insect to relax and to show a negative phototactic movement, but if this is repeated a few times the insect is rapidly deprived of oxygen. It then rises and remains on the surface until this state is remedied.

INHIBITION OF THE ALARM REFLEX BY CERTAIN CHEMICALS.

A number of larvae and pupae were put in solutions of various acids, alkalis, salts and other substances, some of which were toxic and some harmless. A series of solutions of each substance of gradually increasing concentration was used. In nearly all cases it was found that the submerging reflex was inhibited by comparatively weak solutions.

In some cases the solution was apparently not poisonous at all and the larvae seemed perfectly healthy after several hours or even days. Some solutions were poisonous to larvae but not to pupae. The only apparent effect of such solutions was that the insects failed to submerge when a shadow passed over them. They seemed insensitive to light changes or apparently blind. Their muscles and general nervous control seemed unimpaired since they readily submerged when disturbed.

The details of each experiment are given below and in the synopsis which follows it, a blank in the last column indicates that none died at the maximum concentration used.

Sodium hydroxide.—1st and 2nd instar larvae were blinded in concentrations above 0·03 per cent. 4th instars were not blinded even up to 0·2 per cent., but were very easily fatigued and took at least half an hour to recover. They did not react at all in artificial light.

Potassium hydroxide.—All larvae in solutions below 0·13 per cent. and above 2·0 per cent. died. Between these concentrations they survived but above 0·16 per cent. they were blinded.

Ammonium hydroxide.—After forty minutes, all larvae were alive in concentrations up to 0·35 per cent., but were blind in concentrations above 0·1 per cent. Pupae were apparently unaffected and responded normally in concentrations up to 0·32 per cent.

Nitric acid.—After seven hours larvae in concentrations below 0·06 per cent. reacted normally. In concentrations up to 0·12 per cent. they were alive but blind. Above this concentration they were all dead. Pupae were alive but blind in solutions up to 0·18 per cent., but above this were dead.

Hydrochloric acid.—After one hour, all larvae in concentrations above 0·32 per cent. were blind but living. After two hours all above 0·05 per cent. were blind. Those in solutions above 0·32 per cent. were dead. After four hours all were dead.

Sulphuric acid.—After one hour, in strengths up to 0·1 per cent. small larvae reacted normally, but at this strength large larvae were blind. Above 0·14 per cent. all larvae and pupae were blind and above 0·5 per cent. all were dead.

Acetic acid.—After eight hours larvae in solutions up to 0·24 per cent. reacted normally. Above this concentration all were dead. Pupae in solutions up to 0·24 per cent. were normal. From 0·24 per cent. to 0·48 per cent. they were blind. Above this strength they were all dead.

Sodium carbonate.—Above 0·16 per cent. there was apparently rapid fatigue. In concentrations of 0·5 per cent. all larvae were blind and above 1·0 per cent. pupae were also blind. None of these solutions was lethal.

Ammonium carbonate.—After four hours larvae in solutions of 0·14 per cent. were alive but blind. In higher concentrations they died. Pupae reacted normally in solutions up to 0·4 per cent. Above this concentration they were alive but blind. No pupae died.

Sodium chloride.—After nine hours all larvae and pupae in solutions up to 0·5 per cent. were normal. In 1·0 per cent. solution 3rd instar larvae reacted normally. 4th instars were sluggish—some responded and some were apparently blind. In 1·8 per cent. some were dead and all the living ones were blind. Above 2·3 per cent. all larvae were dead. Pupae in solutions up to 5·3 per cent. were alive but blind.

Calcium chloride.—In solutions up to 1·1 per cent. all larvae and pupae were normal. In a solution of 1·65 per cent. small larvae were dead. Large larvae were alive but blind. Pupae were normal. Above 2·0 per cent. all larvae were dead. Pupae were alive but blind in solutions up to 5·5 per cent.

Glucose.—After one hour the reaction was normal in solutions below 10·0 per cent. At 10 per cent. fatigue was immediate. They reacted once and then failed to do so, needing at least five minutes to recover. From 10 per cent. to 20 per cent. all larvae were alive but blind. Pupae reacted normally in solutions up to 20 per cent.

After one day all larvae in solutions up to 6 per cent. were alive but blind. Above this they were dead.

Sucrose.—After two hours in solutions up to 12 per cent. larvae and pupae reacted normally. In solutions from 12 per cent. to 20 per cent. they were alive but blind.

After one day in concentrations below 6 per cent. all reacted normally. In solutions of 8–10 per cent. all were alive but blind. Above 10 per cent. all were dead.

The essential facts embodied in the above results are summarised in the following synopsis :

LARVAE.

	Concentrations above which larvae were blind (%)	Concentrations at which larvae died (%)
Alkalis.		
Sodium hydroxide	0·03	—
Potassium hydroxide	0·16	2·0
Ammonium hydroxide	0·1	0·35
Acids.		
Nitric	0·06	0·12
Hydrochloric	0·95	0·32
Sulphuric	0·14	0·5
Salts.		
Sodium carbonate	0·5	—
Ammonium carbonate	0·14	0·2
Sodium chloride	1·8	2·3
Calcium chloride	1·1	2·0
Sugars.		
Glucose	1·0	6·0
Sucrose	6·0	10·0

PUPAE.

	Concentrations above which pupae were blind (%)	Concentrations at which pupae died (%)
Ammonium hydroxide	0·32	—
Nitric acid	0·06	0·18
Acetic acid	0·24	0·48
Sodium carbonate	1·0	—
Ammonium carbonate	0·4	—
Sodium chloride	1·8	5·3
Calcium chloride	2·0	5·5
Glucose	20	—
Sucrose	12	—

It will be seen that in all cases, apparent blindness occurs some time before death or at lower concentrations than that required for death. In some cases the smaller larvae become blind more quickly than the larger ones, but in others, which appear to be anomalous, the opposite is the case.

The three mineral acids cause blindness very rapidly at very small concentrations. Acetic acid does not cause blindness in larvae below the lethal concentration, but does in pupae. Alkalis require slightly higher concentrations than acids to cause blindness. Salts, especially the chlorides, need a very high concentration and sugars much higher still.

There are several possible theories to account for this apparent blindness. The most likely is that the cuticle of the eye is sufficiently thin and permeable to allow many substances to pass through. Once through this, they can pass between the crystalline cones and have some chemical action upon the retinal pigment or upon the nerve fibres themselves or upon the brain. It is probable, however, that the first effect is upon the retinal pigment.

In addition to chemical actions, there is doubtless an osmotic action. According to Wigglesworth, the haemolymph of a mosquito larva is approximately isotonic with a solution of sodium chloride of 0·8 per cent. This has an osmotic pressure of about 6 atmospheres. All the acids and alkalis used caused blindness at concentrations much below this and therefore the effect was probably chemical. In the cases of the chlorides and of the sugars, however, which were the least toxic of all the substances tried, the minimum concentrations which caused blindness corresponded to osmotic pressures as follows :

Sodium chloride .	13·4	atmospheres
Calcium chloride .	10·8	,,
Glucose . . .	14·9	,,
Sucrose . . .	9·2	,,

It is probable therefore that the effect was due to withdrawal of water from the more delicate cells of the eye, e.g., the retinal cells, and also probably from the nerve fibres and eventually from the optic ganglia and the brain. In the case of salts which penetrate the cuticle, the osmotic effect would be directly on the cells, but in the case of sugars which are less likely to penetrate the cuticle, water would be withdrawn through this from the underlying cells and the ultimate effect would be the same.

It will be seen from the synopses given above that in all cases where pupae were used, these required a much higher concentration than the larvae both to bring about blindness and to cause death. This is probably due to a thicker cuticle, not only over the eye, but also over the whole body.

Summary.

1. Mosquito larvae submerge when a shadow is passed over the water, or by any reduction of the intensity of the light. This can be used as an indication of the functioning or otherwise of the eyes.

2. On each side of the larval head there is a simple eye and anterior to this a compound eye. The latter is much larger and probably more important although both may function.

3. The submerging reflex only takes place when the initial light intensity is greater than about 90 foot-candle power.

4. Diminution in the intensity of any colour or of ultra-violet brings about the submersion reflex.

5. Repetition of the submersion reflex causes a form of " fatigue " or habituation, so that the larvae fail to respond and require a certain period of time to recover.

6. It is possible that *phototonus* normally maintains the attitude of apparent rest on the surface, but that after repeated submersion, lack of oxygen provides a greater stimulus and inhibits submersion.

7. Dilute acids, alkalis, salts and sugars all cause apparent blindness long before any other toxic effects are noticeable.

8. This may be due to permeation of the cuticle of the eye and a chemical action on the retinal cells, or due to a withdrawal of water by osmosis, or to both actions. In the case of chlorides and sugars which are apparently not very poisonous, a very high concentration is necessary to cause blindness. This would suggest that in these cases, the primary effect is osmotic.

9. Pupae are much less susceptible to this blinding effect than larvae and are also able to withstand much higher concentrations without death resulting. This is probably because of the much thicker cuticle.

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BRITISH DIPTERA ASSOCIATED WITH FUNGI.
2.—DIPTERA BRED FROM MYXOMYCETES.

By Professor P. A. Buxton, C.M.G., F.R.S., F.R.E.S.
(*London School of Hygiene and Tropical Medicine.*)

The present paper is hardly more than a simple record of breeding flies from Myxomycetes, from English localities, in 1952 and 1953. Its interest lies in the fact that so far as I am aware it is the first paper which has ever been published on Diptera from these curious organisms. It must be a very rare event to call attention to a new major group of food organisms of insects.

The Myxomycetes or Mycetozoa, to use the terms that are in general use among botanists and zoologists respectively, are sometimes known in English as slime fungi, or slime moulds. They are a remarkable group of primitive organisms, the affinities of which and even the question whether they belong to the plant or animal kingdoms are still matters for discussion. One cannot therefore even state the taxonomic rank of the group, though we may suppose that if they are placed in the phylum Protozoa, then they may be held to constitute a Class. If on the other hand one places them with the fungi, as is done by Langeron and Vanbreuseghem (1952), one has to admit that the Myxomycetes and a few other curious forms stand so far from the rest of the fungi that they constitute one of the primary divisions of the fungi.

I have placed this paper in a series relating to "Diptera associated with fungi." That is not an expression of opinion about the affinities of the Myxomycetes but rather a matter of convenience. Whatever view we take of their affinities, these organisms live commonly on and in rotten wood together with numerous fungi, so that the two groups may be studied and collected together. Moreover, so far as we know, the Diptera bred from the Myxomycetes have affinities with those whose larvae feed in fungi.

The entomologist who requires an introduction to the Myxomycetes should consult Lister (1925). In the briefest terms one may say that the great majority of these organisms produce spores which rupture if they are kept moist, allowing a minute swarm cell to come out. This moves about, divides, loses its flagellum and becomes an amoebula. In process of time a large number of these may unite to form what is called the plasmodium. This is remarkable in that though it may be large it cannot be said to possess any organisation: it consists of a naked mass of protoplasm, containing nuclei which may be exceedingly numerous, and granules of mineral matter. In spite of its extreme simplicity the whole plasmodium is able to move in one particular direction and ingest solid food particles. The plasmodium also exhibits the phenomenon of "protoplasmic streaming." Under moist conditions the plasmodium remains active, but if it becomes dry it passes into a resting stage, the sclerotium. At maturity, the plasmodium develops elaborate sporangia which exhibit specific characters. In many genera the sporangia are minute. In some (e.g. *Fuligo*, *Reticularia*) a large compound fructification, the aethalium, is formed. The dry spores remain viable for long periods and if they are moistened the cycle is repeated. The plasmodia of many Myxomycetes are inside rotten wood, others occur on the surface of dead leaves, dead wood or woody fungi. Some of them even at their largest may be of the size of a pin's head, but others (including *Fuligo septica* referred to below) may be some inches across, and weigh several hundred grams.

TABLE I.—*List of Myxomycetes which have been gathered and studied.*

PHYSARACEAE :			
Fuligo septica Gmel.	August	Gerrards Cross	One fresh aethalium.
,, ,,	Sept.	Kew Gardens	One, old and dry.
,, ,,	June	,,	Many, various ages.
,, ,,	,,	Wheatfen	One, dry.
STEMONITACEAE :			
Comatrichia typhoides Rost.	June	Gerrards Cross	Rather dry
,, sp.	May	,,	,,
AMAUROCHAETACEAE :			
Breffeldia maxima Rost.	August	Gerrards Cross	Fresh aethalium.
RETICULARIACEAE :			
Reticularia lycoperdon Bull.	April	Norwich	Dry aethalium.
,, ,, ,,	Oct.	Gerrards Cross	,,
(Identification of last specimen not completely certain.)			
LYCOGALACEAE :			
Lycogala epidendrum Fries.	Various (12 occasions)	Gerrards Cross	Aethalia of various ages.
,, ,,	May	Norwich	,, ,,
,, ,,	June	,,	,, ,,
TRICHIACEAE :			
Trichia varia Pers.	Oct.	Gerrards Cross	Sticky plasmodia.
,, ,,	Dec.	,,	,,
,, ,,	Sept.	,,	,,
ARCYRIACEAE :			
Arcyria incarnata Pers.	June	Gerrards Cross	Young sporangia.
,, ,,	,,	,,	Older sporangia.
Large plasmodium (undetermined)	May	Burnham Beeches, Bucks.	Large, soft plasmodium.

It seems unlikely that the larvae of any Diptera would feed on the isolated microscopic flagellates or amoebulae, but the relatively massive plasmodium or the young moist aethalium might, and indeed does, constitute a food supply. What little we know at present relates to dipterous larvae feeding in those plasmodia which are found on surfaces of dead wood, etc. These plasmodia may often be collected clean, and if insects are bred, and if the record can be repeated, it is quite satisfactory. With small delicate growths, for instance *Arcyria* or *Trichia,* which have just issued from the wood preparatory to making sporangia, one is compelled to collect a little rotten wood with the Myxomycete. The flies one breeds might therefore come from larvae in the wood, which had not certainly fed on the organism. In such cases I collect, as a control, a large sample of the rotten wood, apparently free of Myxomycete.

It is also possible that certain larvae feed upon the plasmodia which occur inside rotten wood, presumably in minute cavities. As to those larvae, we know nothing : it would not be easy to discover whether Dipterous larvae occurring in such rotten wood were feeding on the plasmodium of a Myxomycete or on one of numerous other organisms (fungi, bacteria, protozoa) which might exist in the same material.

Completely ignorant as we are of the relation of Diptera to Myxomycetes it is not sufficient to record the positive information that a certain fly has been bred from a certain organism. The negative information that I have never bred Diptera, or bred no member of a certain group of Diptera, from several gatherings of a certain Myxomycete is also valuable. I therefore present a list (Table I) of all Myxomycetes which have been gathered, for comparison with the list of insects below. The synonymy and the systematic order follow Lister (1925).

As the total number of species of Myxomycetes recorded from Britain exceeds 180, the seven species which I have been able to examine seem very few : indeed, the list shows that some specimens were rather dry and perhaps hardly likely to contain larvae of Diptera, so that even those seven have been inadequately studied.

My breeding method has been extremely simple; to collect plasmodia or aethalia as free from wood, etc., as possible, and keep them on moist sawdust in a tube or bottle with muslin tied over the mouth. In general I have kept the material about three months in summer : what is collected in autumn is kept until spring. It seems likely that material should be retained longer, if one wishes to be sure of breeding out certain flies, e.g., some Cecidomyids.

Reference is made below to several insects bred from *Fuligo septica* from Kew Gardens, Surrey. It is to be understood that large quantities of coffee grounds (from which coffee had been extracted) were used as a mulch under shrubs, to a depth of a couple of inches. In the summer of 1952 and again in 1953 large quantities of " flowers of tan " (*F. septica*) occurred on the coffee grounds. Among the particles of coffee there was wet plasmodium, bright yellow and resembling custard. On the surface were numerous soft orange plasmodia several inches across, which were turning into crusted dark aethalia. Material in all stages was brought home and an attempt made to breed Diptera from each sample separately.

The Myxomycetes have been identified, in the case of every species, by Dr. R. W. G. Dennis of the Herbarium, Royal Botanic Gardens, Kew. Mr. H. J. Howard, a well-known authority on these organisms, has been good enough to post me living material from the neighbourhood of Norwich. The Diptera have all been examined by specialists, Dr. H. F. Barnes, Mr. P. Freeman or Mr. H. Oldroyd, as was appropriate.

From the specimens listed in Table I the following Diptera have been bred.

NEMATOCERA.

MYCETOPHILIDAE.

Mycetophila vittipes Zetterstedt.

Gerrards Cross, Bucks., England, June, 1953. The young sporangia of *Arcyria incarnata* have only been collected twice (7th and 13th June), on both occasions from a rotten elm log. On each occasion Mycetophilid larvae were seen moving among the stalks of the sporangia on the surface of the wood: they were rather short and wide, and moved in an unusual way, the front end questing from side to side, rather as a Muscid larva does. The habit would be appropriate to a larva browsing through a patch of these small growths. On each occasion, several *M. vittipes* were bred, but none was bred from a considerable quantity of rotten wood collected a foot or two away from the *Arcyria*. The relation of the larva of *M. vittipes* to the *Arcyria* seems to be well established.[1]

Edwards (1925) gives no record of breeding *M. vittipes*, though he remarks that "this is a fairly common form." The discovery that a *Mycetophila* appears to feed regularly on a Myxomycete is surprising. Edwards (1925) recognised 42 British species and recorded that he had bred 14 of them from fungi: several of these have been bred from a number of different species and indeed from fungi of several families. The fact that two-thirds of our species have *not* been bred, in spite of much rearing from fungi is remarkable. Does my record from a Myxomycete point the way?

Platurocypta testata Edwards.

As has already been recorded (Buxton 1952) there is material of this species in the British Museum (Natural History) labelled: "Large numbers reared by H. Britten from a Mycetozoan (*Reticularia lycoperdon* Bullyard).[2] Rostherne Cheshire, 1.vi.31. Larvae not of the shellbearing type." I have recently had the opportunity of repeating this observation: my Myxomycete material was not in good order, and reported by Dennis to be "almost certainly *R. lycoperdon*," collected October, 1953, Gerrards Cross. From it several *P. testata* were bred, but unfortunately I did not observe the larvae. Edwards' MS. note quoted above emphasises that Britten's larvae were not shell-bearers. At an earlier date (1925) Edwards had followed Bloomfield reporting on material collected by Swanton in saying that they "live under limpet-like cases." It seems that Bloomfield was not entirely satisfied in allocating particular larvae to genera: it appears to me that Swanton collected larvae of two genera, one of them shell bearing (perhaps *Phronia*), and associated the wrong larva with the adult *P. testata*.

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[1] While this paper was in the press I bred several *Mycetophila vittipes* from a second species of *Arcyria*, *A. denudata*. This is an interesting record, increasing the list of species on which the larva feeds and confirming its association with this genus of Myxomycete. The material was collected at Gerrards Cross in January, 1954, and the flies emerged in February.

[2] Dr. R. W. G. Dennis points out that the author's name is Bulliard (not Bullyard), a famous early French mycologist (1752–1793).

Platurocypta punctum Stannius.

A brief note (Buxton 1952) has already recorded that I bred this fly in numbers (on one occasion) from *Lycogala epidendrum*, a common Myxomycete on rotten elm wood. I have since bred *P. punctum*, in numbers on both occasions from two lots of material collected at Gerrards Cross in August and September. I have not bred it from ten other lots collected on the same log in May, June, July, August and October. Two lots sent me from Norwich, Norfolk, by Mr. Howard did not yield this insect.

It is very satisfactory to have this clear evidence that both the European *Platurocypta* have been bred twice (and in numbers) from Myxomycetes, each from one species. But the total number of species of Myxomycete examined is so small (Table I) that one could not yet claim that each species of fly is dependent only on a single species of food-organism. There are no records of breeding either species of *Platurocypta* from any fungus or other organism.

SCIARIDAE.

Scaptosciara vivida Winnertz.

Eight specimens, Kew Gardens, June, 1953, from coffee grounds which contained no visible plasmodium of *F. septica*. The association with the Myxomycete is by no means certain.

It has not proved possible for Mr. P. Freeman to identify certain of the Sciaridae.

Bradysia sp.

Kew Gardens, 15th June, 1953. A considerable number of individuals, all apparently of one species, were bred from *Fuligo septica* : they were bred from coffee grounds which contained no visible organism (though probably infected with microscopic stages), and also from very young growth in the " custard " stage, welling up among the coffee grounds. It is remarkable that this insect was not bred from more mature plasmodia or from aethalia. Its relation to *Fuligo* is not established. These insects maintained themselves in the rotten material in the culture jar, as Sciaridae often do. The first generation came out at the end of June, others in July and later.

Bradysia spp.

Specimens referable to *Bradysia* but not necessarily co-specific with the above or with one another have been bred from *Lycogala epidendrum* (May, 1953, Norwich, H. J. Howard) ; also from the rotten wood on which *Arcyria incarnata* was growing (June, 1953, Gerrards Cross).

SCATOPSIDAE.

Scatopse fuscipes Meigen.

Kew Gardens, 15th June, 1953. Only a single specimen, bred from coffee grounds containing small quantities of young plasmodium of *Fuligo septica* : this insect was not bred from the considerable amount of mature plasmodium and aethalium which was studied. Its relation to the Myxomycete is doubtful.

CECIDOMYIDAE.

Three Cecidomyids have been bred, each species on one occasion only. The larvae were never seen and it is *possible* that they were feeding on the fragments of rotten wood, on which the Myxomycetes were collected. That, however, seems improbable, for on each occasion I collected a considerable amount of rotten wood without evident Myxomycetes, as a "control" for the much smaller quantity with the Myxomycete: it was from the latter alone that the organism was bred.

Dr. H. F. Barnes has been good enough to report in a provisional way. Further material is desired, but the existing records point to interesting possibilities.

Brittenia fraxinicola Edwards.

This member of the Heteropezinae was originally described by Edwards (1941) from 18 females found resting on trunks of ash (*Fraxinus*) near Whitby, Yorks. Barnes has one female, indistinguishable from the above (his slide 6833), caught by B. R. Laurence as prey of *Tachypeza nubila* Meigen, on a spruce trunk, Harpenden, Herts, 1950.

The only information on life history is that I have bred a single female from young sporangia of *Arcyria incarnata* on very rotten elm wood, Gerrards Cross, collected 7th June, 1953 (Barnes' slide 8770).

Bremia sp.

One male belongs to the Cecidomyinae, subtribe Trifila. It falls in the genus *Bremia* sens. lat. Though most of the larvae of that group are predaceous, some woodeating species have been included by Kieffer. I have bred this specimen from rather mature aethalia of *Lycogala epidendrum* from Norwich (H. J. Howard). Only a single male has been bred, on one of the 14 occasions on which this Myxomycete has been collected. This may prove to be a casual record, due perhaps to a mature larva chancing to pupate in the material.

Undetermined Cecidomyid.

Two males, of a single species, not at present determined, fall into sub-group B of group 2 of the Campylomyzini of the Lestreminae, according to Edwards' key. They were bred from young sporangia of *Arcyria incarnata*, on very rotten elm wood, Gerrards Cross, collected 7th June, 1953 (Barnes' slide 8935, 8936). None was bred from samples of the wood which was free of *Arcyria*.

BRACHYCERA.

EMPIDIDAE.

Drapetis (*Crossopalpus*) *nigritella* Zetterstedt.

Kew Gardens, 15th June, 1953. Two specimens bred from coffee grounds containing very small amounts of young plasmodium of *Fuligo septica*, but none bred from considerable amounts of older plasmodium and aethalium: relation to the Myxomycete is doubtful. The larva is presumably a predator, but Mr. J. E. Collin tells me that nothing appears to be known of the life history of this species. The association with *Fuligo* may be fortuitous.

ATHERICERA.

SAPROMYZIDAE.

Lonchaea vaginalis Fallén.

Kew Gardens, 11 and 15 June, 1953. Several specimens on two occasions from the fresh soft plasmodia of *Fuligo septica*. In this case the association of the insect with the Myxomycete appears established, but that does not imply that *Fuligo* is the larva's only food.

BORBORIDAE.

Leptocera fontinalis Fallén.

Kew Gardens, 15th June, 1953. Bred from two batches of *Fuligo septica*, both from the state which is very young and quite liquid, resembling custard, and from coffee grounds in which the Myxomycete was very sparse. Professor O. W. Richards tells me that he knows no breeding records of this very common species. He and I agree that we have no knowledge of the insect being associated with fungi.

DROSOPHILIDAE.

Drosophila repleta Wollaston.

Kew Gardens, 15th June, 1953. Several specimens bred from rather old dry material of *Fuligo septica*. I have also bred *D. repleta* from two Agaric fungi, *Lactarius vellereus* and *Paxillus involutus* (Tonbridge, Kent, August). Perhaps it breeds in a wide range of decaying organisms.

SEPSIDAE.

Nemopoda nitidula Fallén (*cylindrica* Fabr.).

Gerrards Cross, April, 1953. Two specimens bred from a large gelatinous plasmodium of an unidentified Myxomycete.

MUSCIDAE.

Hylemyia cilicrura Robineau-Desvoidy.

Kew Gardens, 15th June, 1953. From young, yellow plasmodium of *Fuligo septica*, four specimens: none bred from older more mature growths. Mrs. Mary Miles informs me that the larva of this fly is primarily saprophytic. It feeds on remains of crops and other plant refuse; also on roots of living plants of many kinds.

DISCUSSION.

The justification for publishing this paper is the very interesting fact that certain British flies, not apparently rare, breed habitually in certain Myxomycetes. These organisms have not, as it seems, been previously recorded as food of Diptera in any part of the world, except for a recent preliminary note (Buxton, 1952).

Evidence which one would regard as satisfactory that a certain insect breeds in these organisms might be that the larvae had been seen in the Myxomycete, but not in the material in which it is growing, and that the flies have been bred in numbers, and on more than one occasion. Evidence could also be obtained by dissecting the larvae and identifying material coming from the Myxomycete and not from the decomposing wood on which that organism is growing: that, however, I have never done.

By far the most interesting records relate to three species of Mycetophilidae all of them bred from Myxomycetes, each breeding repeated and none of the flies known to breed on anything else.

Mycetophila vittipes is a member of a genus of which there are more than 40 British species, of which about one-third have been bred from fungi, many of them repeatedly. Though a considerable amount of work has been done attempting to breed Diptera from fungi (particularly by Edwards and myself) this species has never been bred, though the adult is not rare. I have, however, bred it on two separate occasions*, several specimens each time, from the Myxomycete *Arcyria*, and the larvae have been seen both times moving about among the stalks of the sporangia on the rotten wood on which the organism grows. The two species of *Platurocypta* (*P. testata* and *punctum*) have also both been bred twice, several specimens on each occasions, from Myxomycetes. Our present information is that each species of fly has been bred only from one species of Myxomycete; but that must be accepted with caution in view of the very small number of Myxomycetes which have yet been examined. The two food organisms, *Reticularia* and *Lycogala* are referred by Lister to different families (Table I), but are both placed in the same suborder, the Anemineae.

With regard to the flies other than Mycetophilidae, there is fairly satisfactory evidence that certain species are associated with Myxomycetes; it is often clear that the Myxomycete is far from being the sole food of the larva of the fly and that the relationship is in no way specific; most of the larvae are probably saprophagous. The following insects would appear to fall in this group:

Bradysia sp. (species associated with *Fuligo septica*).
Brittenia fraxinicola.
Cecidomyid, Campylomyzini, (*Arcyria incarnata*).
Lonchaea vaginalis.
Drosophila repleta (probably from decomposing *Fuligo*; saprozoic).
Leptocera fontinalis.
Hylemyia cilicrura.

With regard to certain insects, the evidence is at present imperfect. The records may perhaps be due to the larva having fed elsewhere and moved into the Myxomycete at the time of pupation. The following insects perhaps fall in this group:

Scatopse fuscipes.
Scaptosciara vivida.
Bradysia (two species, associated with *Arcyria incarnata* and *Lycogala epidendrum*)
Bremia sp.
Drapetis nigritella.
Nemopoda nitidula.

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* The footnote, page 166, records a third occasion.

To sum up, it is clearly proved that certain Myxomycetes are the food organism of three species of Mycetophilid flies. A considerable number of other Diptera have been bred from a small number of Myxomycetes ; some of these appear to be generally saprophagous : some of the records are perhaps accidental. It is remarkable that no Phorids (*Apiochaeta* or *Megaselia*) have been bred. The larvae of these organisms are often abundant in decomposing fungi of several families, as we know from my own collecting and the work of Colyer, Schmitz and others. There is a remarkable contrast between the small *Lycogala* and minute *Arcyria*, which have insects specifically feeding upon them, and the large semi-liquid *Fuligo*, which is not known to support any specific flies, but which is fed on by a considerable number of saprophagous forms.

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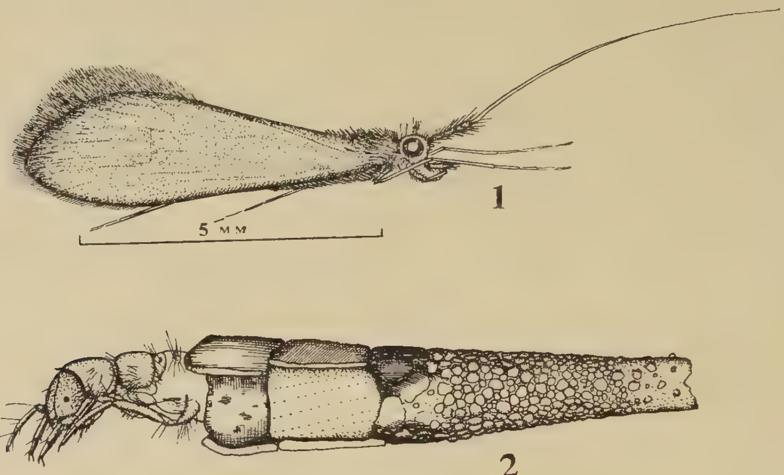
LARVAE OF THE BRITISH TRICHOPTERA—48.

By N. E. Hickin, Ph.D., F.R.E.S.

Crunoecia irrorata Curtis (Lepidostomatidae).

This is one of the species described in detail by Nielsen (1942) from Danish material. Only those characters have been described, therefore, which are required to enable an identification to be made. I am indebted to Mr. A. Peacey, who kindly sent me larvae of the species, which he had collected on 15th January, 1954, from a small fast stream near his home at Brimscombe, near Stroud, Glos. They appeared to be feeding on dead leaves and rotting wood. Mr. Peacey had previously reared this species from larvae collected from a stream near Bisley, Glos., in 1953.[1]



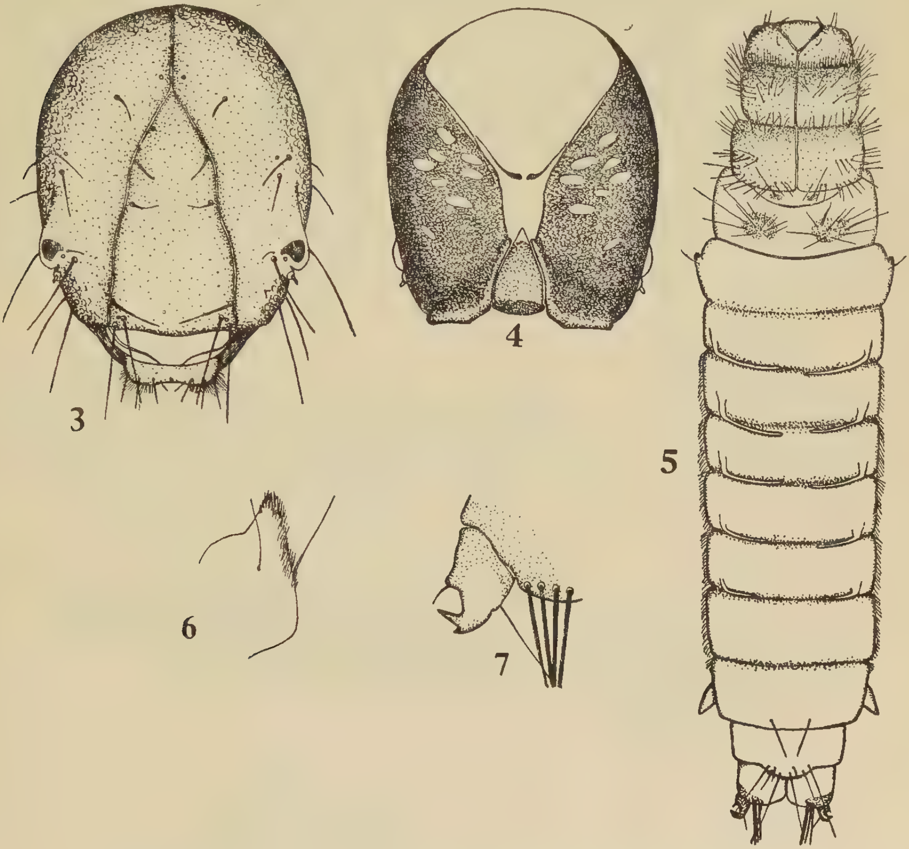
Figs. 1–2.—*Crunoecia irrorata.* (1) Side view of adult. (2) Larva in case.

Larva : length 6–7 mm., width 1–6 mm. When extracted from case abdomen assumes variety of shapes quite unlike any other Caddis larva I have examined. *Case* : length 7–9 mm., width 2 mm. constructed first of sand grains, then fragments of rotting wood, dead leaves and other vegetable matter, to give square cross-section reminiscent of *Lepidostoma hirtum* although not constructed in quite such a regular manner. *Head* from above : rich chestnut-coloured, reddish to naked eye, devoid of marks, strongly rugose. Shape of clypeus and chaetotaxy as in fig. 3. *Head* from beneath : dark chestnut-coloured, strongly rugose. Muscle-spots much lighter in colour and not rugose. Gular sclerite triangular, oral margin very dark chestnut brown ; in the area of the genal suture genae membraneous and light cream in colour with two black points at their aboral end. Metanotum of two distinct parts, small anterior part in which a pair of single bristles is situated, and large posterior part with two large groups of bristles. Dorsal protuberance on first abdominal segment absent, lateral protuberances acute, covered with short bristles and hairs. Pairs

[1] A further batch of this series was reared to adult stage by the author ; emergence taking place on 7th June, 1954. Their identification was confirmed by Mr. D. E. Kimmins.

PROC. R. ENT. SOC. LOND. (A). 29. PTS. 10–12. (DEC., 1954).

of single filiform gills present arising from posterior edge of second to sixth abdominal segment on dorsal and ventral surfaces. Lateral line inconspicuous, consisting of short light-coloured hairs, and extending from the third abdominal segment to the beginning of the eighth. On the eighth segment a pair of lappets directed posteriorly and somewhat eversible. Anal claw with auxiliary claw.



Figs. 3–7.—*Crunoecia irrorata.* (3) Head of larva from the front. (4) Head from below. (5) Body of larva from above. (6) Lateral protuberance, abdominal segment I. (7) Anal claw.

Summary.

The larva of *Crunoecia irrorata* Curtis is described and figured, and a figure of the adult given.

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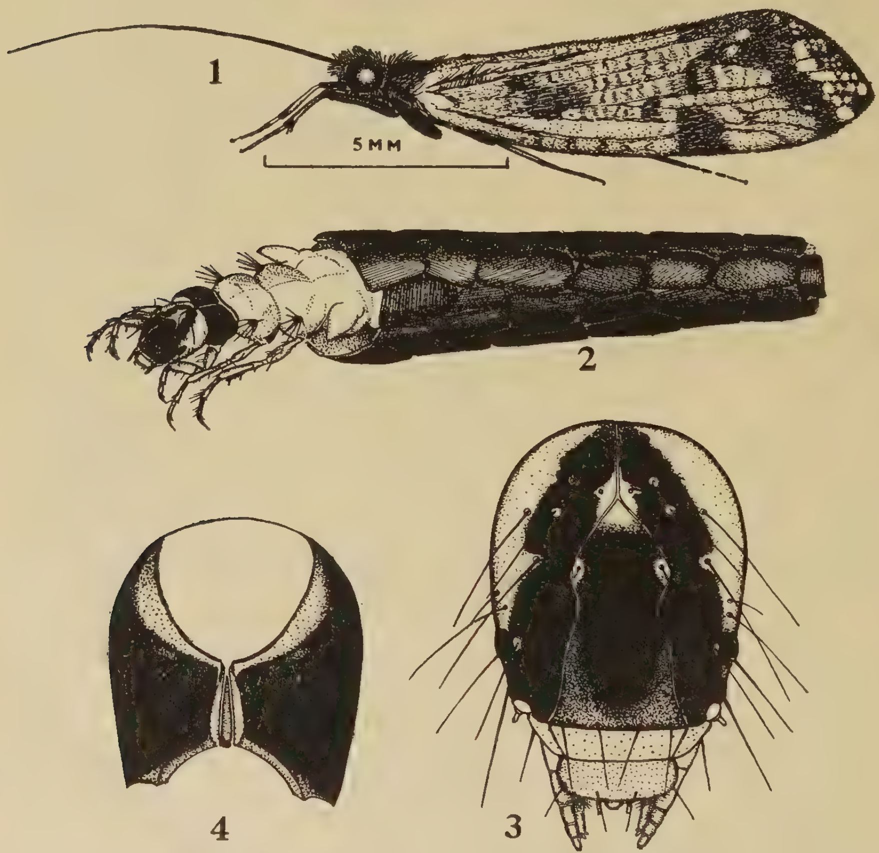
LARVAE OF THE BRITISH TRICHOPTERA.—49.

By N. E. Hickin, Ph.D., F.R.E.S.

Trichostegia minor Curtis (Phryganeidae).

Adults of this uncommon caddis fly were found in profusion by Mr. A. Peacey on 11th July, 1953. They were resting in the crevices of the bark of oak trees surrounding Cannop Pool, Forest of Dean, Glos. This is the first record for the county. I accompanied Mr. Peacey to Cannop Pool on 20th February, 1954, when we were successful in finding about three dozen larvae. They were mostly found between two and three feet from the edge of the water, and at a depth of two feet. There had previously been a period of severe frost. The



Figs. 1–4.—*Trichostegia minor.* (1) Adult. (2) Larva in case. (3) Head of larva from the front. (4) Head of larva from behind, mouthparts omitted.

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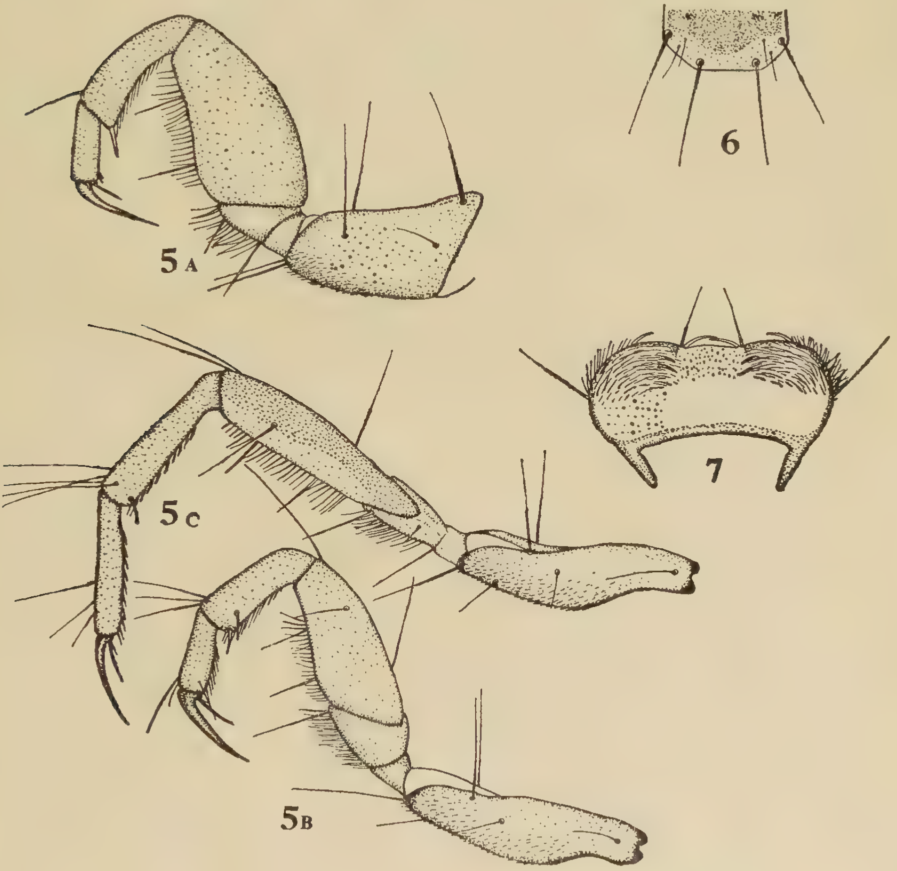
larvae appeared to be most common at the entrance to the bay-like indentations, and larvae of *Limnephilus rhombicus* L., *L. flavicornis* Fabr., and *Glyphotaelius pellucidus* Retz. were common also.

Larva.—Length 15–18 mm., width 2·5 mm. Head, pronotum and legs dark sooty-brown (head with pale yellowish areas). Meso- and metanotum not sclerotised, mauve-purple and green. Abdomen bluish-green near thorax, elsewhere lime-green, gills white, anal sclerite light brown. *Case :* length up to 25 mm., width 3 mm. Of cut pieces of leaf, etc., not generally arranged in a spiral, tapering posteriorly. *Head :* see fig. 3 for disposition of dark areas on upper surface. Ventral areas of genae very dark brown to black, aboral margin greyish. *Labrum* hairy underneath, with a pair of claw-like bristles on each side. *Mandibles* brown, folds of genae on each side light greyish-yellow. Pair of bristle-pits on each side of gular sclerite. *Abdomen :* median dorsal protuberance on first abdominal segment absent, lateral protuberances large. *Gills* present on segments I to VIII. Anal claws with additional claws.



Figs. 5–7.—*Trichostegia minor.* (5) Legs of larva: A. prothoracic, B. mesothoracic, C. Metathoracic. (6) Anal sclerite. (7) Labrum.

SUMMARY.

The larva of *Trichostegia minor* Curtis is described and figured, and a figure of the adult given.

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THE REACTION OF A GRASSHOPPER TO AN ODOROUS MATERIAL HELD NEAR ONE OF ITS FEET (ORTHOPTERA : ACRIDIDAE).

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Romalea microptera (Beauvois), the Florida lubber grasshopper, is an unusually favourable insect for studying the reaction obtained when limited areas of the body surface are exposed to a stimulating agent. This species is one of the largest of all North American grasshoppers and the metathoracic feet (tarsi and pretarsi) of a female which is clinging to the cage wall may be as much as 15 cm. apart and 8 cm. away from the nearest portion of the abdomen. Both sexes are brachypterous, slow in their movements and docile when handled. They are hardy and are easily reared in the laboratory on a diet of common weeds, lettuce, fruits, flowers, and grains.

The work reported here was carried out with 14 adults—5 females and 9 males—which had undergone their final moult from four to six weeks earlier. They were kept together in a large, screened cage and the tests were made on individuals which were clinging to the inner side of the screen in a resting position, and had the ventral surface turned towards the observer. In testing the response to odours, a drop of one of the materials listed in Table I was placed on a small square of filter paper—or, in the case of menthol, wrapped in a piece of cotton gauze—which was then picked up with forceps and held outside the screen a few millimetres away from the undersurface of one of the feet. In 917 out of 1000 trials the foot was lifted away from the screen, either at once or in less than 20 seconds, while in 83 such tests no reaction occurred within the 20 second time limit, and the paper was then withdrawn. Before each trial a piece of plain filter paper was held close to the foot for 20 seconds, as a control. In 994 out of 1000 of these control tests the foot remained motionless, while in six tests the foot was lifted.

A summary of the results obtained with ten different odorous materials is given in Table I. With a single exception—oil of eucalyptus—the reactions to the various odours were similar. The foot tested was lifted from the screen and then slowly replaced. Except for occasional movements of the maxillary and labial palps, all other parts of the body remained motionless. The response with oil of eucalyptus, in contrast, was immediate and violent. In many of the tests with this oil, the insect suddenly threw itself backwards with such force that it lost its hold on the screen, and fell to the bottom of the cage. Others drew back and then moved quickly to some other part of the screen. None failed to react immediately. The tests with oil of eucalyptus were more difficult to obtain than were those with the other substances used, for much time was lost waiting for the excited insect to become quiet again.

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Table I.—*The reaction of* Romalea microptera *adults to essential oils and other odorous materials held near one of the feet. Twenty-second time limit for each test.*

	Females.				Males.			
	Control.		Experimental.		Control.		Experimental.	
	No reaction.	Foot lifted.	No reaction.	Foot lifted.	No reaction.	Foot lifted.	No reaction.	Foot lifted.
Oil of eucalyptus	49	1	0	50	50	0	0	50
Oil of camphor	49	1	1	49	48	2	0	50
Oil of cloves . .	50	0	0	50	50	0	3	47
Methyl salicylate	50	0	3	47	50	0	1	49
Oil of bergamot	50	0	2	48	48	2	3	47
Menthol . .	50	0	5	45	50	0	0	50
Oil of thyme .	50	0	8	42	50	0	0	50
Oil of cinnamon	50	0	10	40	50	0	8	42
Oil of anise .	50	0	10	40	50	0	8	42
Cedarwood oil .	50	0	10	40	50	0	11	39
Totals .	498	2	49	451	496	4	34	466
Per cent. .	99·6	0·4	9·8	90·2	99·2	0·8	6·8	93·2

The results of the experiments with repellant materials were so definite that we may conclude from them that sense organs which are stimulated by odorous materials are present on the feet. The sensory structures on the different regions of the leg of *Romalea microptera* have not yet been studied, but it is highly probable that they are similar to those found on the legs of other species of grasshoppers by the writer (Slifer, 1950, 1954 and unpublished data). If such proves to be the case, the several types of sense organs will probably be so distributed that it should be possible, following the amputation of various parts, to decide which kind is involved in the response just described.

In addition to the substances listed in Table I, all of which had a repellant effect, two odorous foods which are eaten eagerly by the grasshoppers were tested. These were well-ripened banana and freshly-picked rose petals. Individuals kept in a cage with an abundant supply of other foods will usually begin eating either of these materials at once when it is offered to them. In these tests, as in those with repellants, a small portion of banana or rose petal was

Table II.—*The reaction of* Romalea microptera *adults to odorous foods held near one of the feet. Twenty second time limit for each test.*

	Females.				Males.			
	Control		Experimental.		Control.		Experimental.	
	No reaction.	Mouth-parts moved.	No reaction.	Mouth-parts moved.	No reaction.	Mouth-parts moved.	No reaction.	Mouth-parts moved.
Banana .	49	1	50	0	50	0	44	6
Rose petal .	50	0	46	4	45	5	41	9
Total and per cent.	99	1	96	4	95	5	85	15

brought near the underside of the foot and any movement of the mouthparts or other appendages which occurred within 20 seconds was noted. Before each test a piece of filter paper was held near the foot as a control. No movements of the tested feet occurred and the number of trials in which the mouth-parts moved is low (Table II). In the fifteen tests with males where positive results were obtained, the odour may have reached the mouth-parts in air currents, and stimulated the sense organs on them directly. Since the males are smaller than the females, and the distance between the tested foot and the mouth-parts correspondingly less, this may be the explanation for the larger number of positive results with males. After a series of trials had been run, individuals which had just been tested were removed from the cage, and a piece of banana or rose petal held near the mouth to be certain that the food was still acceptable. The mouth-parts moved rapidly when this was done, and the insects usually began to eat the food offered within a few seconds.

We may conclude from the experiments reported here that certain of the sense organs which are present on the feet of the grasshopper are stimulated by repellant odours, but that they are not affected by the odour of an attractive food.

The writer wishes to thank Mr. and Mrs. J. Lee Taylor who caught the *Romalea* nymphs in Florida and brought them to Iowa City.

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INDEX

absinthii, Macrosiphoniella, 85
Aculeate Hymenoptera : feeding habits, 119–123
Acyrthosiphon, 76, 84–85
adjuncta, Pilaria, 135
Aëdes, 157
aequalis, Promachus, 82
agrostis, Schizaphis, 85
Alcimus, 83
alpestris, Stenophylax, 96
Andrena, 122
Apiochaeta, 171
Apis, 66–67, 119, 121–123
Aquatic insects, demonstration of physical gill, 51–54
Arhopalus, 99–112
assimilis, Tinodes, 94
atomarius, Grammotaulius, *larva,* 89–91
avenae, Macrosiphum, 85

bajulus, Hylotrupes, 100, 105, 108
batava, Pilaria, 135
beccarii, Trigona, *biology,* 66–67 ; *wax,* 69
bicolor, Triaenodes, *larva,* 154
Bombus, 119, 120, 122, 123
Bradysia, 167, 170
brassicae, Pieris, 130, 132–133
Bremia, 168, 170
Brittenia, 168, 170

Callicorixa, 20–21
Carpophilus, 45–49
Caterpillars : metamorphosis in integument, 129–134
Cecidomyid, *undetermined,* 168, 170
centralis, Limnephilus, *larva,* 96
Chaetosiphon, 84–85
Chironomid midges : numbers at Khartoum, 124–128.
Chorosoma, 32, 33
Chorthippus, 23
Chrysopa *spp.,* 76
cilicrura, Hylemyia, 169, 170
Cladotanytarsus, 124–128
clathrata, Neuronia, 96
Coccinella, 47
communis, Aëdes, *structure of larval eyes,* 157
concinna, Sigara, 20–21
conspersa, Triaenodes, *larva,* 153–155
cooki, Rhopalosiphum, 84
Corixa, 20, 51–54
Corixidae, *taken in light-traps,* 17–22
Criocephalus, 99
Crossopalpus, 168
Crunoecia, 172–173
Culex, 156–157
Culicidae, *structure of larval eyes,* 156–157
cylindrica, Nemopoda, 169

deesae, Stenobracon, *mechanism of oviposition,* 1–6
deflexa, Drosophila, 114, 116
denoiti, Trigona, *biology,* 63–65 ; *wax,* 68.
destructor, Acyrthosiphon, 85
Diptera associated with fungi, 163–171
discicollis, Pilaria, 135
dispar, Tanita, 23–29 ; *flight muscles,* 29
Dixippus, 129
domestica, Musca, *leucopoiesis,* 39–41
dorsalis, Rhyacophila, *larva,* 59–61, 147–149 ; *key,* 151
dorsata, Apis, 121
Drapetis, 168, 170
Drosophila, *diapause in,* 114–118, 169, 170
dubia, Orgyia, 75

elutella, Ephestia, 116
Ephestia, 116, 130–133

falleni, Sigara, 20–21
ferus, Arhopalus, *biology,* 99–112 ; *life history,* 99–101 ; *diapause,* 101–105 ; *larval growth,* 105–107, *larval* life, 107–111 ; *economic aspect,* 111–112
filata, Pilaria, 135
flavicornis, Limnephilus, 175
flavopilosus, Promachus, 81–83
florea, Apis, 121
fontinalis, Leptocera, 169, 170
fossarum, Sigara, 20
fragaefolii, Chaetosiphon (Pentatrichopus), 84–85
fragariae, Macrosiphum (Sitobion), 85
fraxinicola, Brittenia, 168, 170
fuscipes, Scatopse, 167, 170

Galleria, 130, 132–133
geoffroyi, Corixa, 52
Glossina, 83
Glyphotaelius, 175
Gonioscelis, 82
Grammotaulius, 89–91
griseicolle, Simulium, 124
gulo, Lamyra, 81–83
guyénoti, Drosophila, 116

Habrobracon, 6
Hesperocorixa, 20
hirtum, Lepidostoma, 172
holci, Schizaphis, 85

Honeybees : communication, 141–144
hortorum, Bombus, 119, 120
Hylemyia, 169, 170
Hylotrupes, 100, 105, 108
hyoscyami, Therapha, 32
Hyphydrus, 51
Hypotrigona, 62

indica, Apis, 121
iridipennis, Melipona, 121
irrorata, Crunoecia, *larva*, 172–173
Ithycerus, 47–48.

juglandis, Habrobacon, 6

Karoo, Mesocelis sp., *from Eastern*, 71–75
kühniella, Ephestia, 130–133

Lamarckiana sp. : *flight muscles : post embryonic development*, 23–29 ; *comparison with* Saussurea stuhlmanniana (*Karsch*) *and* Tanita dispar (*Miller*), 29 ; *no. of instars*, 23–25 ; *development of exoskeleton*, 25–26 ; *of wings*, 26–27 ; *of flight muscles*, 27–29
Lamyra, 81–83
lateralis, Micropterna, *larva*, 96, 145–146
lateralis, Sigara, 20
latipennis, Stenophylax, *larva*, 55–57
Lepidostoma, 172
Leptocera, 169, 170
lewisi, Tanytarsus (Cladotanytarsus), 124–128
Limnephilus, 96–97, 175
linnei, Hesperocorixa, 20
Lonchaea, 169, 170
lophospermum, Macrosiphum, 84
lunator, Megarhyssa, 6
Lype, 93–94

Macrosiphoniella, 85
Macrosiphum, 37, 84–85
maidis, Rhopalosiphum, *males and use of males in aphid taxonomy*, 84–85
Megachile, 122
Megarhyssa, 6
Megaselia, 171
melanogaster, Drosophila, 116
Melanostoma, *sp.*, 80
Melipona, 121, 122
mellifera, Apis, 67, 119, 121
mellonella, Galleria, 130, 132–133
Mesocelis, *parthenogenesis*, 71–75
Metamorphosis in integument of caterpillars, 129–134
metempsytus, Culex, 156
Micromus, 76–80
microptera, Romalea, *reaction to odorous material*, 177–179
Micropterna, 96, 145–146
minor, Acyrthosiphon, 85
minor, Trichostegia, *larva*, 174–176
miriformis, Myrmus, 32–34, 37
moesta, Hesperocorixa, 20
montana, Mesocelis, 71–75
morsitans, Glossina, 83
Mosquito larvae, vision and blindness, 156–162
munda, Rhyacophila, *larva*, 151 ; *key*, 151
Musca, 39–41
Mycetophila, 166, 170
Myrmus, 32–34, 37
Myzus, 84

negligens, Promachus, 83
Nemopoda, 169, 170
nemoralis, Pilaria, 135
Neuronia, 96
nigritella, Drapetis (Crossopalpus), 168, 170
nigrolineata, Sigara, 20
nitens, Drosophila, 116, 118
nitidula, Nemopoda, 169, 170
Notonecta, 51

obliterata, Rhyacophila, *larva*, 147, 149–150 ; *key*, 151
obscura, Drosophila, 117
obsoletus, Carpophilus, *note on anatomy and morphology of external genitalia*, 45–49
Orgyia, 75

pallidula, Tinodes, 94
papillosa, Tessaratoma, *wing venation*, 9
parallelus, Chorthippus, 23
parumpunctatus, Rhopalus, *notes on the early stages*, 32–38 ; *oviposition*, 32 ; *description of ova*, 32–33 ; *development of ova*, 33–34 ; *nymph, first, second and third instars*, 34–36 ; *biological observations*, 36–38
Parthenogenesis, Mesocelis, 71–75
pectoralis, Prosopis, 119
pellucidus, Glyphotaelius, 175
Pentatrichopus, 84
persicae, Myzus, 84
phaeopa, Lype, *larva*, 93–94
Pieris, 130, 132–133
Pilaria, 135
pilosella, Ulomorpha, 135
pipiens, Culex, 156–157
pisum, Acyrthosiphon, 76, 84
Platurocypta, 166–167, 170
Platycheirus *sp.*, 80
Pollenia, 117
porosus, Acyrthosiphon, 85
praeusta, Callicorixa, 20–21
Promachus, 81–83
Propylaea, 76
Prosopis, 119, 122
Proventriculi of various aculeate Hymenoptera, 119–123
Pseudolimnophila, *structure and function of respiratory horns of pupae*, 135–140
punctata, Corixa, 20, 52
punctum, Platurocypta, 167, 170

quatuordecimpunctata, Propylaea, 76

reducta, Lype, *larva*, 93
reparda, Coccinella, 47

repleta, Drosophila, 169, 170
rhombicus, Limnephilus, 175
Rhodnius, 129
Rhopalosiphum, 84–85
Rhopalus, 32–38
robusta, Drosophila, 116–118
Romalea, 177–179
rosae, Macrosiphum, 37
rostocki, Tinodes, 93
rudis, Pollenia, 117
ruficrus, Neuronia, *larva*, 96
rufifrons, Drosophila, 116
rufovillosum, Xestobium, 107
Rhyacophila; 59–61 ; *taxonomy of larvae*, 147–152

sahlbergi, Corixa, 52
sahlbergi, Hesperocorixa, 20
Saussurea, 23–29
Scatopse, 167, 170
Scaptosciara, 167, 170
schillingi, Chorosoma, 32
Schizaphis, 85
scutatus, Platycheirus, 80
scutellata, Pilaria, 135
septentrionis, Rhyacophila, 59–61, *larva*, 147, 150–151 ; *key*, 151
Sigara, 20–21
Simulium, 124
Sitobion, 85
staudingeri, Trigona, *biology*, 67–68 ; *wax*, 69
stellatus, Stenophylax, *larva*, 55–57
Stenobracon, 1–8
Stenophylax, 55–57, 96
striata, Sigara, 20–21
stuhlmanniana, Saussurea, 23–29 ; *flight muscles*, 29
subobscura, Drosophila, 117
sylvarum, Bombus, 119, 120

taeniopus, Alcimus, 83
Tanita, 23–29 ; *flight muscles*, 29
Tanytarsus, 124–128
Tessaratoma, 9–16 ; *wing venation*, 9 ; *male genitalia*, 9–11
Tessaratominae, *status*, 11–15
testata, Platurocypta, 166, 170
Therapha, 32
Tinodes, 93–94
togoensis, Trigona, *biology*, 65–67 ; *wax*, 69
Triaenodes, 153–155
Trichostegia, 174–176
Trigona, *notes on biology and waxes of four species*, 62–70
tristis, Drosophila, 117

Ulomorpha, 135
unicolor, Tinodes, 94
urichii, Culex, 156

vaginalis, Lonchaea, 169, 170
variegatus, Micromus, 76–80
Vespa, 119, 121, 122
vittatus, Limnephilus, *larva*, 96
vittipes, Mycetophila, 166, 170
vivida, Scaptosciara, 167, 170
vulgaris, Vespa, 119

wollastoni, Callicorixa, 21

xanthopogon, Gonioscelis, 82
Xestobium, 107